An Operational Demonstration of A Vessel Ice Management System for Lake Melville and Approaches

Final Report

Newfoundland and Labrador
Department of Development
Department of Regional Economic Expansion

October 1982

NORDCO Limited

AN OPERATIONAL DEMONSTRATION OF A VESSEL ICE MANAGEMENT SYSTEM FOR LAKE MELVILLE AND APPROACHES

Submitted to:	The Department of Development, Government of Newfoundland and Labrador and the Department of Regional Economic Expansion, Government of Canada
Submitted by:	NORDCO Limited
File Ref.:	182-81
Date:	August 12, 1982

FUNDING FOR THIS STUDY WAS JOINTLY PROVIDED BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION AND THE NEWFOUNDLAND AND LABRADOR DEPARTMENT OF DEVELOPMENT UNDER THE PLANNING SUBSIDIARY AGREEMENT OF THE CANADA/NEWFOUNDLAND GENERAL DEVELOPMENT AGREEMENT

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EXECUTIVE SUMMARY

During the period March 21 to 26, 1982 NORDCO Limited carried out an operational demonstration of a vessel ice management system for Lake Melville and approaches. This project was sponsored by the Department of Development, Government of Newfoundland and Labrador and the Department of Regional Economic Expansion, Government of Canada. The objective of the study was to illustrate the present operational capability to utilize remote sensed data to provide ice analysis, ice forecasting and ship routing services to a ship transiting the Labrador pack ice.

An evaluation of the remote sensed data collected indicated that the data coverage during the project was excellent. Coverage was obtained from aerial ice reconnaisance flights using visual observations and imaging radar, satellites equipped with visual and infrared sensors and from the CCGS SIR JOHN FRANKLIN which was stationed in the pack during the study collecting ice data. The only required parameter for which good coverage was not obtained was the location of icebergs. This problem was mainly due to problems with identifying icebergs using the different systems and in the case of the Canadian Government ice reconnaissance flights the absence of a mandate to observe icebergs.

Twice daily NORDCO used all the available observational data to produce a chart showing current ice conditions in the study area. An evaluation of these charts indicated that they represent the state-of-the-art in manual ice forecasting. The accuracy of the 12 hour ice forecast produced during this study was also investigated but due to the relatively static ice conditions experienced during the study no conclusions could be reached.

A comparison of the recommended shipping routes provided with a standard route indicate that there was only a slight reduction of transit time by using the recommended route. However, this analysis is biased towards situations that will result in small differences in transit times by the type of ice conditions that existed during the

study. Under more normal conditions the analysis may have provided quite different results. The ability of the ship routing service to reduce the hazard from icebergs and multi-year ice was also investigated. This analysis indicated that further research is required on observing icebergs and the effect of icebergs on navigation.

1.0 INTRODUCTION

This report describes and evaluates an operational demonstration of a vessel ice management system for Lake Melville and approaches (Figure 1) carried out by NORDCO Limited for the Department of Development, Government of Newfoundland and Labrador, and the Department of Regional Economic Expansion, Government of Canada. This demonstration is one of a number of studies sponsored by the Department of Development in order to define the technical feasibility, cost, and risk associated with winter long shipping into Lake Melville. The objective of the demonstration was to illustrate the present operational capability to utilize remotely sensed data in providing ice information as though to a vessel in winter transit through the Labrador pack ice and across Lake Melville. The terms of reference of this study are included in Appendix A.

The operational demonstration was implemented during the period March 21 to 26, 1982 in conjunction with other ice research projects carried out in the Lake Melville area by the Department of Development and the RADARSAT[1] project. The project was originally intended to take place during the period March 11 to 23, 1982 but had to be delayed and shortened due to problems with obtaining the CCGS SIR JOHN FRANKLIN which was used to collect data for this and the other projects.

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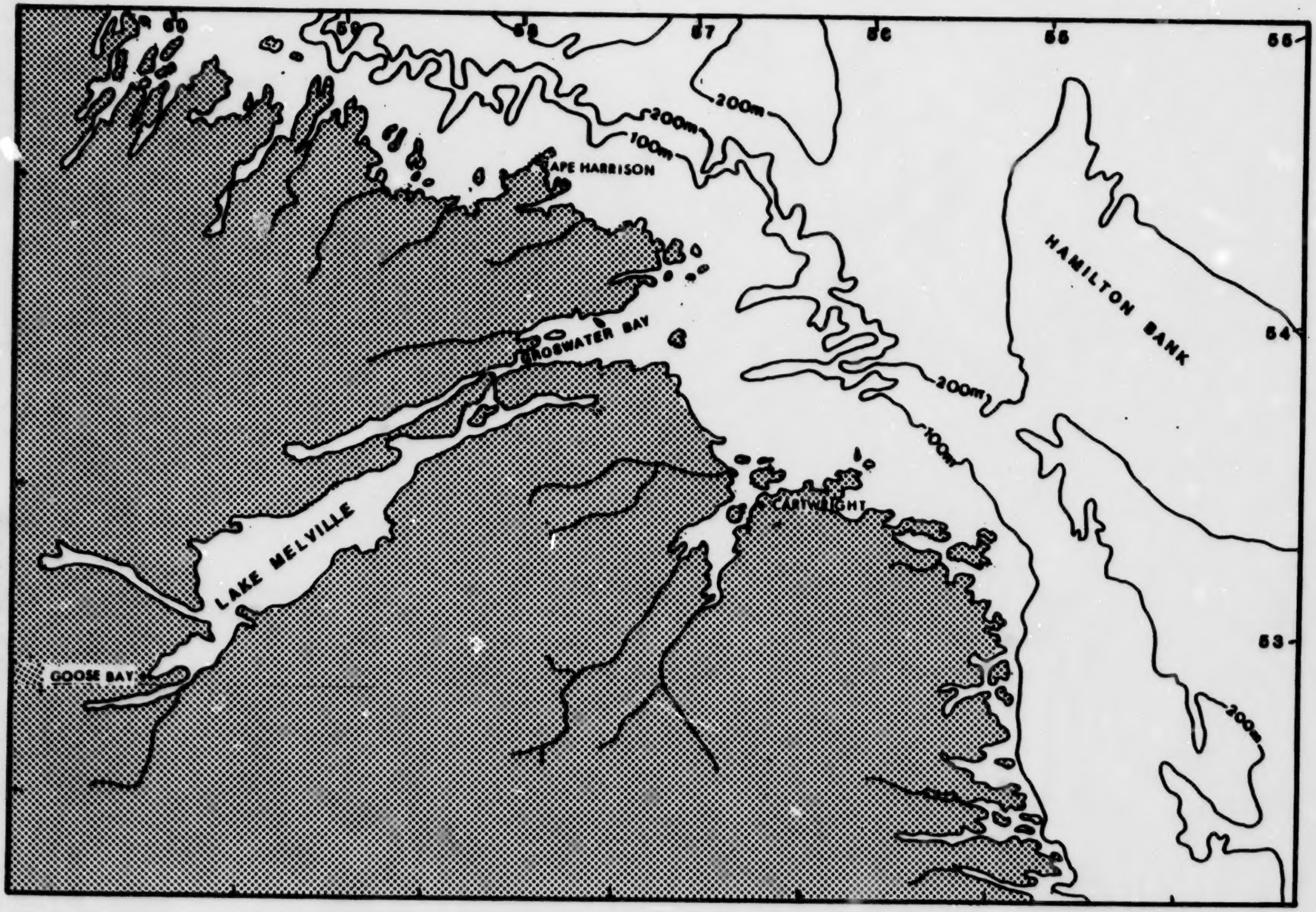
[1] RADARSAT is a Government of Canada project designed to develop a radar equipped satellite.



60
59
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55
54
53
200m
200m
100m
200m
100m
200m
APE HARRISON
HAMILTON BANK
GROSWATER BAY
CARTWRIGHT
LAKE MELVILLE
GOOSE BAY

FIGURE 1: STUDY AREA

2.0 SERVICES PROVIDED

To provide a realistic test of the vessel ice management system the project was organized to approximate as closely as possible actual operating conditions during a commercial shipping operation into Lake Melville. Twice daily at 1230 GMT (0830 NST) and 1930 GMT (0600 NST) the NORDCO Environmental Forecasting Office in St. John's prepared an ice information package designed to aid an hypothetical ship preparing to transit the Labrador pack while en route from Europe to Lake Melville. This package consisted of:

(a) a brief discussion of current and forecast weather conditions in the study area;

(b) a map showing current ice conditions in the approaches to Lake Melville;

(c) a map showing forecast ice conditions for 12 hours from the time of issue, and

(d) a description of the recommended route through the pack ice.

The twelve ice information packages issued during the study are included in Appendix B of this report.

In an actual operating situation the ice information package would have been transmitted, via radio FAX, to the cargo ship before it reached the ice edge. The master of the vessel would then decide either to use the recommended route or select his own route using the ice chart for guidance. Updated forecasts would be issued at regular intervals during the voyage or when new ice data were received. This service would continue until the vessel entered the Lake or reached the outer edge of the pack ice when outbound. Since there was no vessel transiting the pack ice during the operational demonstration the ice information packages were filed for later analysis. The ice information packages were not sent to the CCGS SIR JOHN FRANKLIN since its role was to collect ice data and not to act as the cargo ship.

3.0 METHODOLOGY

3.1 Introduction

This section outlines the data base and forecasting procedures used to prepare the ice information package and describes the criteria used to select the recommended route.

3.2 Data Base

The observational data used as input for the current ice analysis included satellite imagery, aerial ice reconnaissance charts and ship reports. The satellite imagery was received at the NORDCO Environmental Forecasting office on a K-560 photofax. The images used were the NOAA-7 visual (Figure 2) and infrared, received at approximately 0600 GMT and 1800 GMT each day, and the GOES visual and infrared images, received approximately every half hour. Due to the poor resolution of the GOES imagery it was of very little value. It was hoped to receive NOAA-6 imagery during the project but this satellite was experiencing technical problems during this period. Contact prints of all satellite imagery used are included in Appendix C.

Aerial ice reconnaissance of the study area was provided by the Atmospheric Environment Service of Canada (AES), Electra Aircraft and the Canadian Center for Remote Sensing (CCRS) CV-580 aircraft. The Electra used was stationed in Gander and is staffed by experienced AES ice observers. This aircraft is equipped with a side-looking airborne radar (SLAR), laser profilometer, infrared line scanner and aerial cameras. If visual conditions exist the AES ice observers prepare a map based on visual observations but if the area is cloud covered then the map is based on the SLAR imagery. At the end of each flight these maps were sent to Ottawa and then on to NORDCO via telecopier.

The CCRS aircraft was stationed in Goose Bay and equipped with a synthetic-aperature radar (SAR) and a number of other sensors. It was originally intended to carry out real-time analysis of the SAR imagery from the CCRS aircraft and use these data to prepare a ice map which

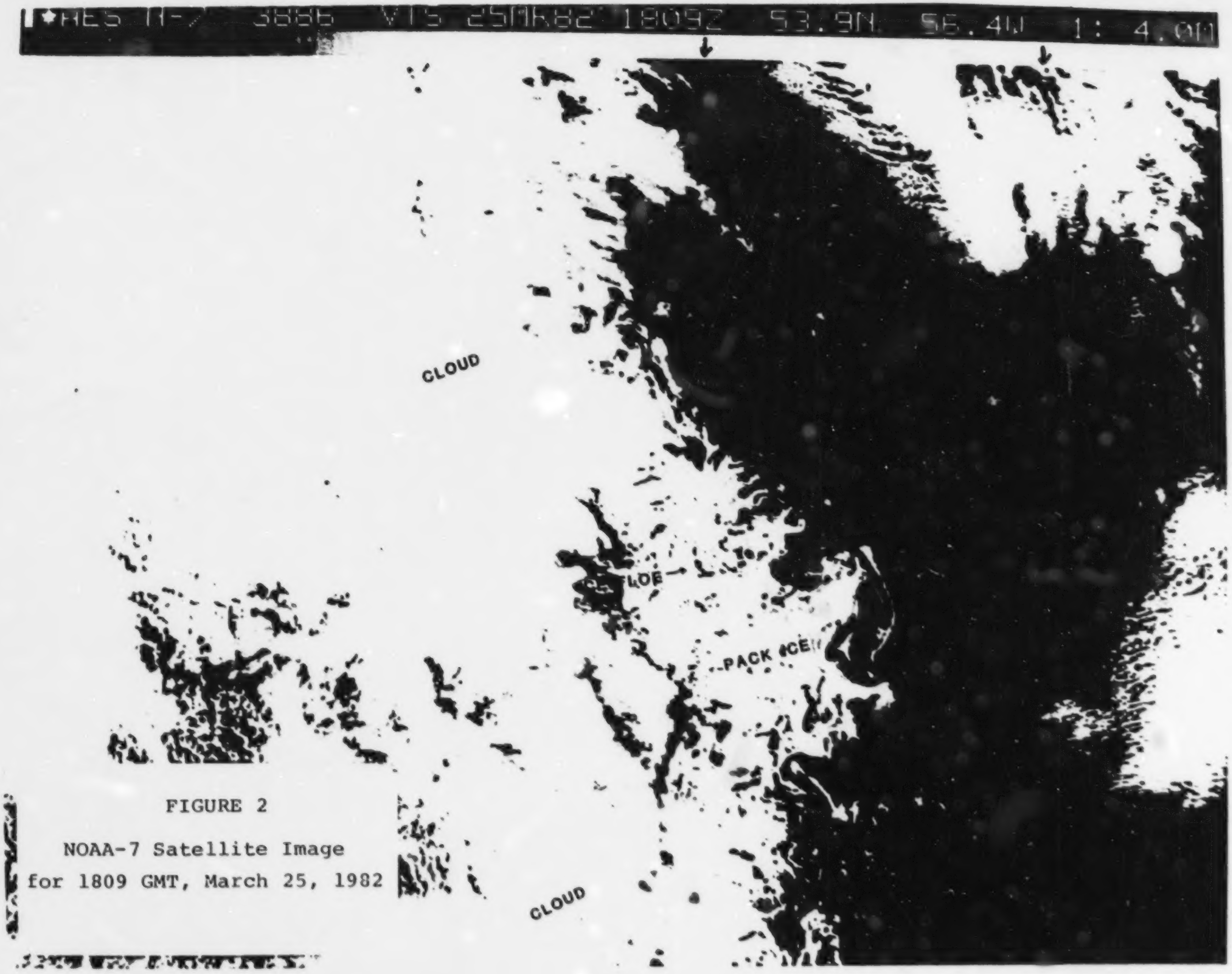

AES N-7 3886 VIS 25MAR82 1809Z 53.9N 56.4W 1: 4.0M
CLOUD
LOE
PACK ICE
CLOUD

FIGURE 2

NOAA-7 Satellite Image
for 1809 GMT, March 25, 1982

would be transmitted to the NORDCO Environmental Forecasting office after each flight. To meet this objective NORDCO engaged INTERA consultants Ltd. of Ottawa to provide an experienced SAR interpreter. Unfortunately due to the operating routine of the CCRS aircraft, insuffient SAR imagery was collected to make this worthwhile. Instead the INTERA analysist produced an ice map based on his visual observations from the CCRS aircraft. After each flight these ice maps were telecopied to the NORDCO Environmental Forecasting office from Goose Bay. Since the INTERA observer did not have extensive experience with visual mapping of ice and had no previous experience in this region, his maps were considered to be not as reliable as the AES maps. The AES ice maps received during this project are included in Appendix D and the ice maps prepared by the INTERA observer are included in Appendix E.

Standard AES format meteorological and ice reports were received from the CCGS SIR JOHN FRANKLIN at 1200 GMT, 1500 GMT, 1800 GMT and 2100 GMT each day. These reports were transmitted through the normal channels used for marine meteorological observations and were received at the NORDCO Environmental Forecasting office via the AES teletype circuits. The ice message included information on: ice type, concentration, thickness, relief, surface features, stage of melting, extent of topography, height of topography, ice drift, openings in the ice, snow cover and icebergs. The messages received at NORDCO and the key for decoding the ice messages are included in Appendix F.

The current ice analysis charts issued by AES were received at the NORDCO Environmental Forecasting office during the study (Appendix G). However these charts were not used in the analysis since they arrived after the 1930 GMT chart was prepared. An additional problem with the AES analysis charts was that during the study period AES was experiencing trouble with the direct radio fax link between the aircraft and Ottawa and, therefore, their flight data did not reach Ottawa untill after the current ice analysis chart was completed. Since NORDCO issued two forecast per day the flight data was included in the morning NORDCO chart.

3.3 Forecasting Procedures

The procedures used for preparing the current ice chart and 12 hour forecast were similar to those used by Ice Forecasting Central (AES) in Ottawa and most other national ice forecasting organizations. Prior to preparing the current ice chart all available observational data were collected and plotted. Since most of these data would have been collected hours or even days prior to the time the map is prepared, the ice conditions had to be updated using standard ice forecasting techniques. These basically involve redistributing the ice using emperical relationships that describe how the ice moves in response to winds and ocean currents, and in addition, accounting for any ice growth or melt that might result from temperature conditions. The 12 hour forecast was prepared using the same techniques except that the current ice chart was used as the initial conditions and forecast rather than actual winds were used.

The forcing functions used to calculate the ice drift were the wind field and ocean currents. The wind data used to update the ice information for the current ice conditions chart were actual winds observed on the CCGS SIR JOHN FRANKLIN, while in the pack, and geostrophic winds determined from weather maps prepared at NORDCO. The wind data used to prepare the 12 hour ice forecast were from a wind forecast prepared by the duty meteorologist at the NORDCO Environmental Forecasting office. Since there is practically no data on ocean currents in the study area it was assumed that there were no currents in Grosswater Bay and outside this area a southeasterly current of 0.25 kts. was assumed.

3.4 Route Selection

The recommended shipping route included with the ice information package was designed to aid the Master of the vessel in selecting the safest and most economical route through the pack ice. The criteria used for selecting the recommended route were:

(a) select the shortest feasible route;
(b) considering (a) select the route with the lowest ice concentrations and thinnest ice;
(c) avoid areas where there is 10/10 or 9+/10 concentrations of mainly first-year ice;
(d) avoid areas where the ice is expected to be under pressure;
(e) and avoid areas where there are high concentrations of icebergs or multi-year ice.

The reasons for using criteria (a) and (b) are obvious while criteria (c) and (d) were used since previous studies have shown that a vessels speed is reduced considerably when the ice concentration reaches 9+/10 and that even powerful vessels may become trapped when the ice is under pressure (Bradford 1972 and 1973 and NORDCO 1980). Criterion (e) was included since these ice features would represent a potential hazard to the vessel.

4.0 1982 IN PERSPECTIVE

4.1 Introduction

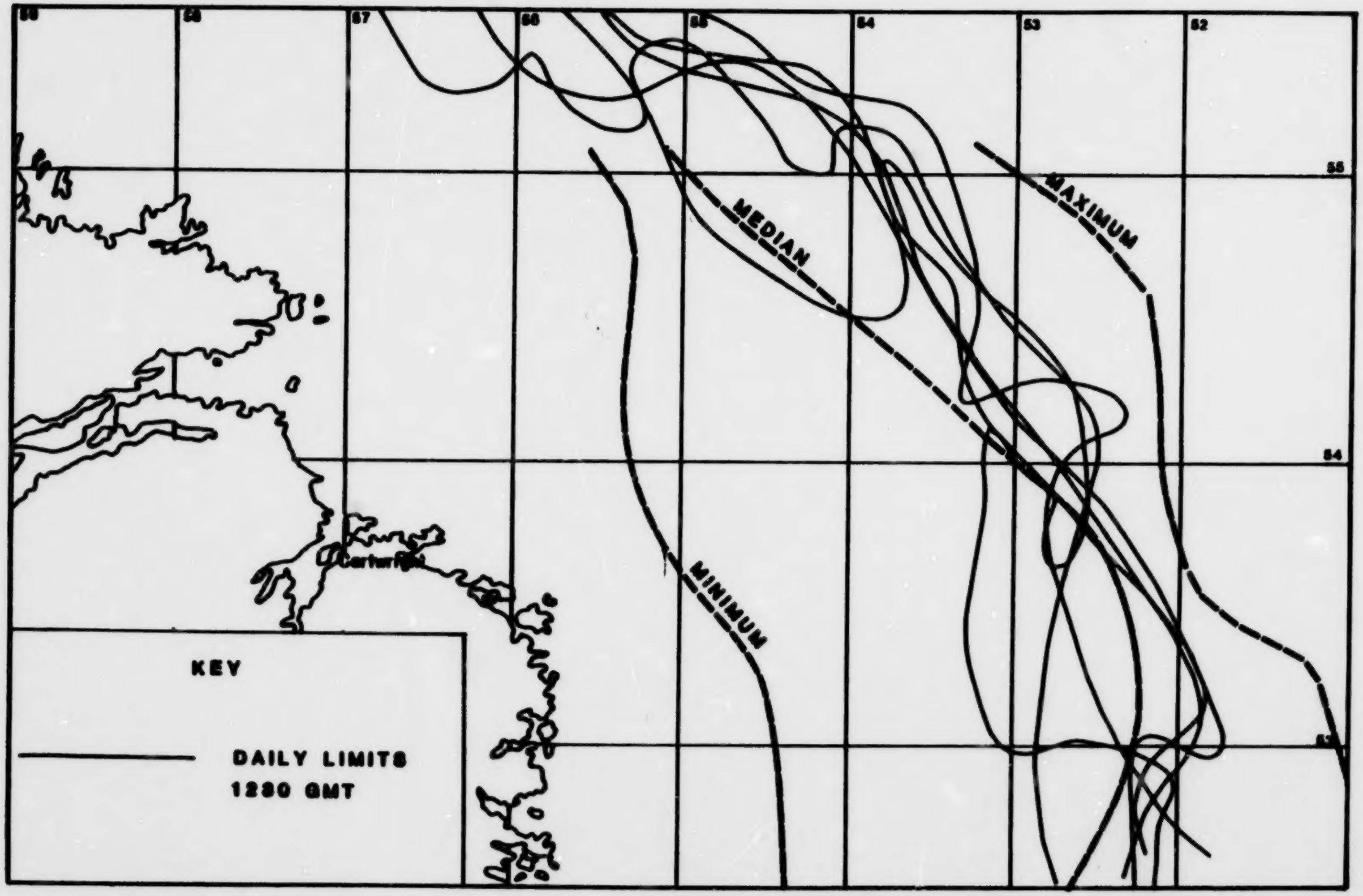
The success of any vessel ice management system will depend to a considerable extent on the environmental conditions that exist in the study area. The objectives of this section are, therefore, to evaluate environmental conditions during the study period and determine what effect they had on the routes selected and to compare these conditions with the norm for the area to establish how representative conditions were during the study period.

4.2 Sea Ice

Up to late January, 1982 ice conditions along the Labrador coast were less severe than normal, but below normal temperatures and northwest winds during February and March resulted in a rapid growth of the pack ice and by the start of the operational demonstration ice conditions in the study area were near or slightly more severe than normal. Comparison of the daily ice limits during the study period with the norm for March 26 (Figure 3) show that north of 54°N the ice was further east than normal while south of 54°N it was near its normal position. Ice concentrations during the study period were also similar to normal (Figure 4) with the highest concentrations (9/10 and 9+/10) situated west of 54°W and relatively open pack east of this meridian. The relative proportions of the different ice types in the pack west of 54°W were first-year 65%, grey-white 10%, grey 15% and new 5%. These proportions are relatively close to the normals for southern Labrador given by Markham (1980, p. 14). No old ice was indicated on any of the NORDCO or AES ice maps and the research team on the CCGS SIR JOHN FRANKLIN was only able to locate two old floes. This is not surprising since there was no residual ice left in Baffin Bay at the end of the previous summer and therefore old ice would not be expected on the Labrador coast till the arrival of the old ice from Smith Sound in late April.

One aspect of ice conditions in the study area that requires further investigation is the number of large floes that were visible on the satellite imagery (Figure 2). These floes ranged in size

FIGURE 3 DAILY (1230 GMT) ICE LIMITS FOR MARCH 21-26,1982 AND THE MEDIAN, MAXIMUM AND MINIMUM ICE LIMIT FOR MARCH 26 (FROM MARKHAM 1980)


59
58
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56
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54
53
52
55
54
53
MAXIMUM
MEDIAN
MINIMUM
Cartwright
KEY
DAILY LIMITS
1230 GMT

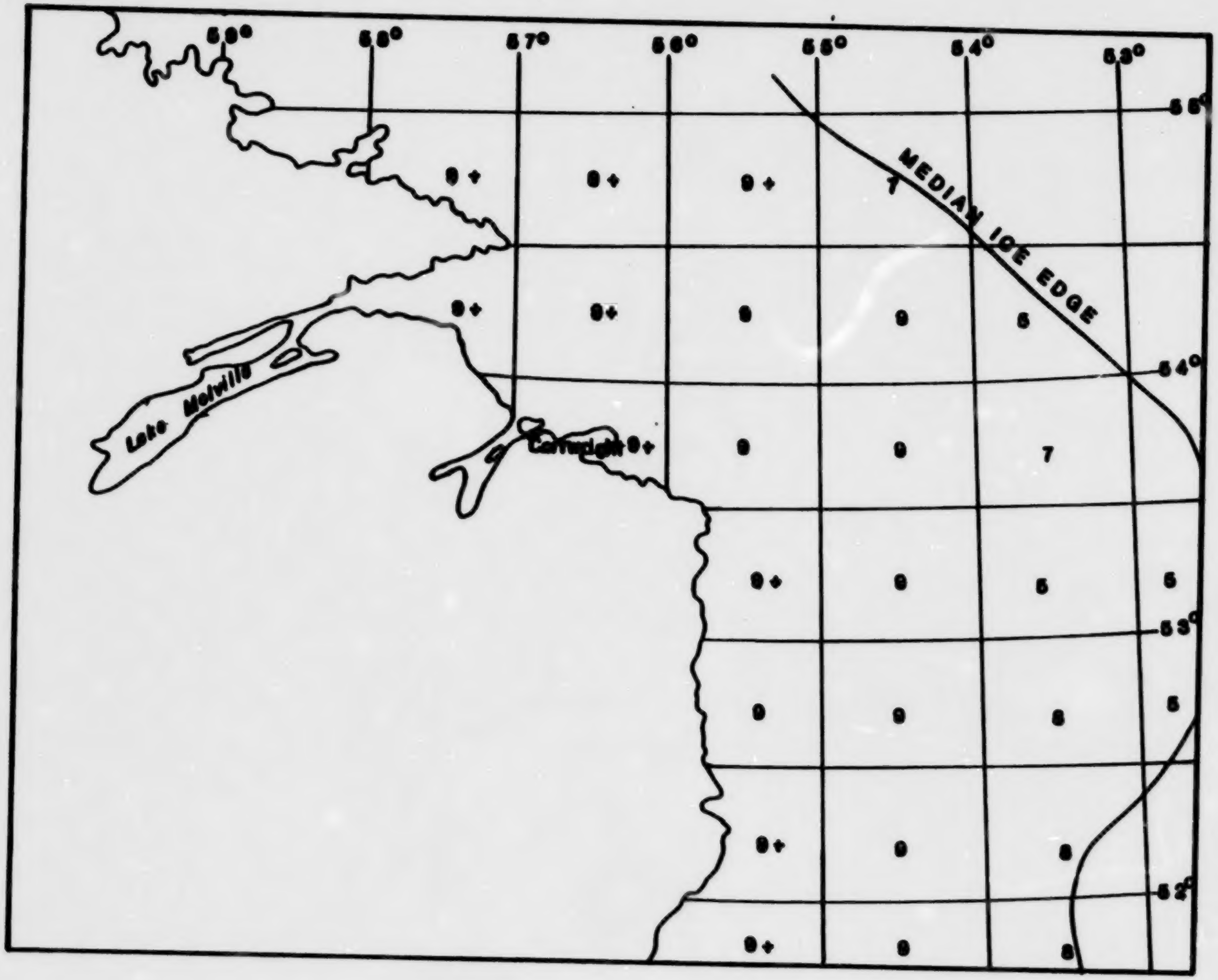

59°
58°
57°
56°
55°
54°
53°
55°
54°
53°
52°
MEDIAN ICE EDGE
Lake Melville
Cartwright

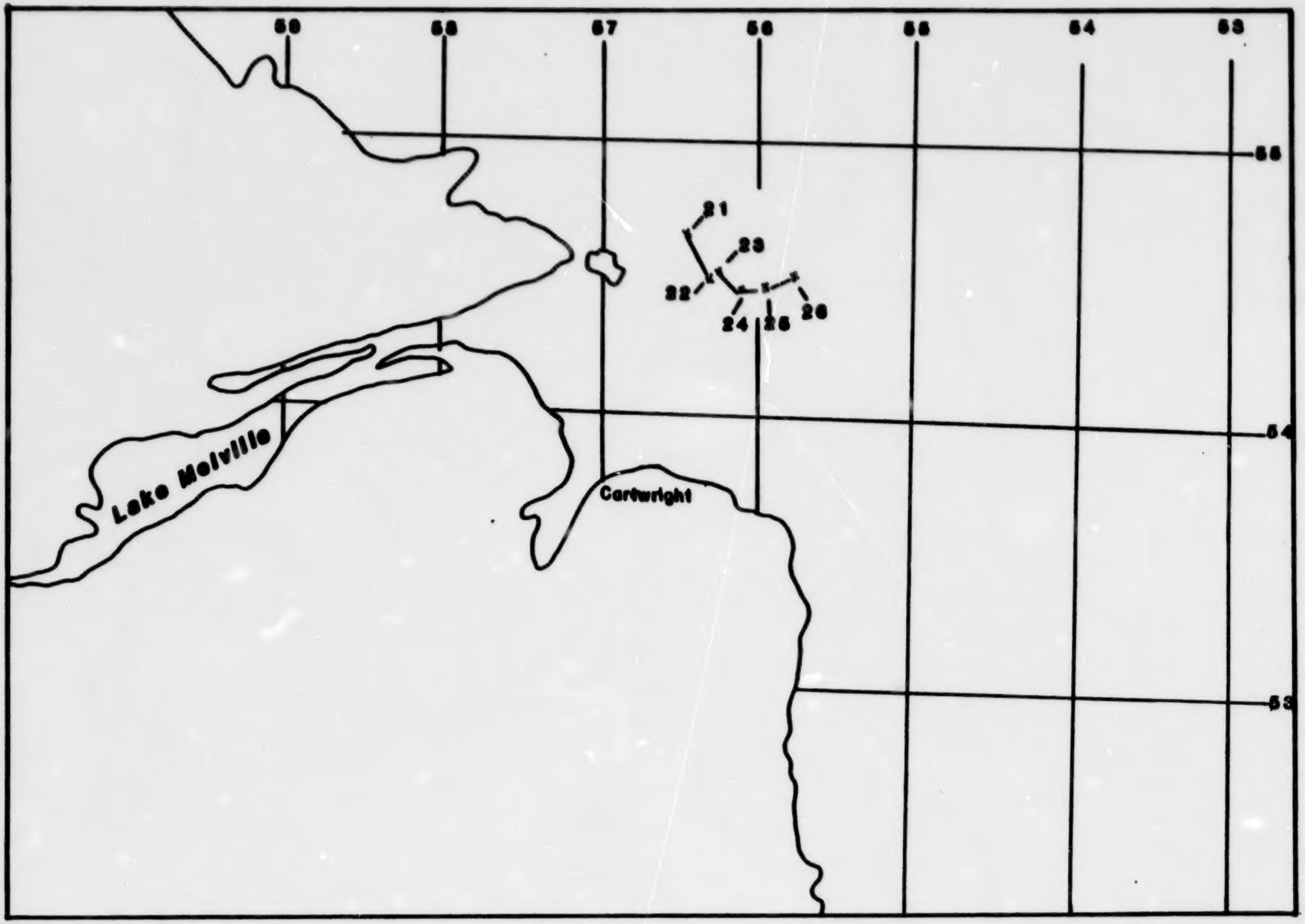
FIGURE 4 NORMAL ICE CONCENTRATION (tenths) IN STUDY AREA

from 100 sq. Km to 1000 sq. km and were clearly different from the surrounding ice. There was no indication of open waters within these floes and the fact that there were often leads along the lee edge of the floe indicates that they were solidly cemented together rather than a random collection of ice. Over the study period a number of these floes were observered to drift southeast at from 0.2 to 0.4 kts. (Figure 5). This provides further evidence that these floes were not random collections of ice. Analysis of SAR imagery, discussions with the INTERA ice observer and the personnel on the CCGS SIR JOHN FRANKLIN indicated that these floes were not identifyable from either the ship or aircraft. From these discussions and previous experience in this area it would appear that these floes are collections of first-year floes that become cemented together with younger ice.

The fact that these floes hold together for so long and their appearance on the satellite imagery indicate that ice concentrations within then must be at or near 10/10. In addition the appearance of these floes on the infrared satellite imagery indicate that they are considerably thicker or more concentrated than the surrounding ice. These facts would indicate that navigation through these floes should be more difficult than navigation through the surrounding ice. The recommended routes selected were, therefore, designed to avoid these large floes. In an attempt to determine what effect these floes would have on navigation, the cruise report for the FRANKLIN voyage was searched for data during periods when the vessel was crossing one of these floes but no such situations were identified. The effect of these floes on navigation should be addressed in any future field programs in this area.

4.3 Icebergs

None of the aerial ice reconnaissance data collected during this project was specifically intended to collect iceberg distribution statistics. The AES ice charts (Appendix D) do indicate the presence of some icebergs but since it is not part of their mandate to observe icebergs these sightings are generally not a good indicator of the total iceberg population in an area. Similarly the INTERA ice


59
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54
53
21
22
23
24
25
26
Lake Melville
Cartwright

FIGURE 5 DRIFT OF THE LARGE ICE FLOE SHOWN ON FIGURE 2 DURING THE PERIOD MARCH 21-26 ,1982

observer attempted to plot the position of any icebergs observed but his other duties prevented him from plotting the position of all icebergs observed. Despite the lack of a reliable data base the following comments can be made regarding the iceberg distribution in the study area:

(a) the icebergs tend to be concentrated between 54.5°W and 56.5W,
(b) the icebergs tend to be found in clusters, and
(c) the density of observed icebergs in the study area is between 3 and 6 icebergs per half degree latitude by one degree longitude square.

The iceberg distribution maps for the Labrador coast prepared by Gustajtis and Buckley (1977) show a similar distribution of icebergs sightings but indicate that the normal iceberg density in this area is much higher. Since the number of icebergs observed on the Grand Banks later in the season indicates that 1982 was an average iceberg year the difference between the number observed and the normals could indicate that many icebergs were not observed during the study. Since the recommended route was often selected to avoid high concentrations of icebergs any future vessel ice management system should place more emphasis on observing icebergs.

4.4 Meteorological Conditions

During almost the entire study period the Lake Melville area was under the influence of high pressure systems which resulted in light to moderate southwesterly winds. Observations recorded on the FRANKLIN indicates that the mean wind speed during the study period was approximately 11 kts. while the normal wind speed in this area is 15 kts. The light offshore winds experienced during the study resulted in an almost complete absence of pressure situations in the pack ice. In addition, due to the light winds, there was almost no change in ice conditions during the study period and, therefore, the 12 hour ice forecast generally did not indicate any change in ice conditions.

Both of these factors make it difficult to evaluate a vessel ice management system since the situation in which it would be most useful is during the passage of a low pressure system south of the area when the ice can come under pressure and ice conditions are changing rapidly.

The high pressure systems that influenced the study area also resulted in almost cloud free conditions during the entire study period. This allowed constant monitoring of ice conditions using satellite imagery. Under normal conditions this area would only be expected to be cloud free 50% of the time.

4.5 Ocean Currents

There is very little information available on ocean currents in the study area. Some of the International Ice Patrol Bulletins for the 1950's show dynamic topography along a section from 53.5°N, 56.0°W to southern Greenland and based on these maps there appears to be southeasterly currents both inshore and offshore from Hamilton Bank (Figure 1) with a weak eddy over the bank. A number of studies based on analysis of ice drift indicates that there is a general southeasterly flow in this area. Although there are current meter data available for this area no synoptic analysis of currents in this area could be located.

Analysis of ice floe drift during the study period indicate that the floes drifted southeast at from 0.2 to 0.4 kts (Figure 5). After these drift speed were corrected for wind drift the current component was estimated at from 0.2 to 0.3 kts.

5.0 PROJECT EVALUATION

5.1 Introduction

The objective of this section is to evaluate the ice information packages issued during the study and determine if they would be of value to a commercial shipping operation. To carry out this evaluation the ice information packages are divided into four sections: input data; ice analysis; ice forecast; and route selection. Each of these is evaluated separately. An important part of this evaluation is to determine how the results of the project would vary if some aspect of the project, for example the environmental conditions or type of input data, were changed.

5.2 Evaluation of the Input Data

The observational data used to prepare the ice information package were: GOES satellite imagery; NOAA-7 satellite imagery; SLAR flight maps from AES; visual flight maps from AES; visual flight maps from the CCRS aircraft; SAR data from the CCRS aircraft; and ship reports from the CCGS SIR JOHN FRANKLIN. The schedule for receiving these data is shown in Figure 6. During three days, March 22-24, the area was covered by satellite imagery, ship reports and observations from both aircraft, while for the remaining days there was coverage from at least two of these sources. This coverage is excellent when compared with a normal week in this area which would have one flight by the AES aircraft and 3 or 4 days with satellite coverage.

The type of ice information obtained varied with the data source used (Table 1). The reports from the CCGS FRANKLIN provided the most detailed source of data but due to the small area covered they were of limited value. Generally the most useful data source was the aerial ice charts. The visual ice charts provided most of the information required for selecting the recommended shipping route. The only problem with these charts was the uncertainty about the number of icebergs observed (See Section 4.3). The aerial ice charts based on SLAR data did not provide as detailed information on ice types and

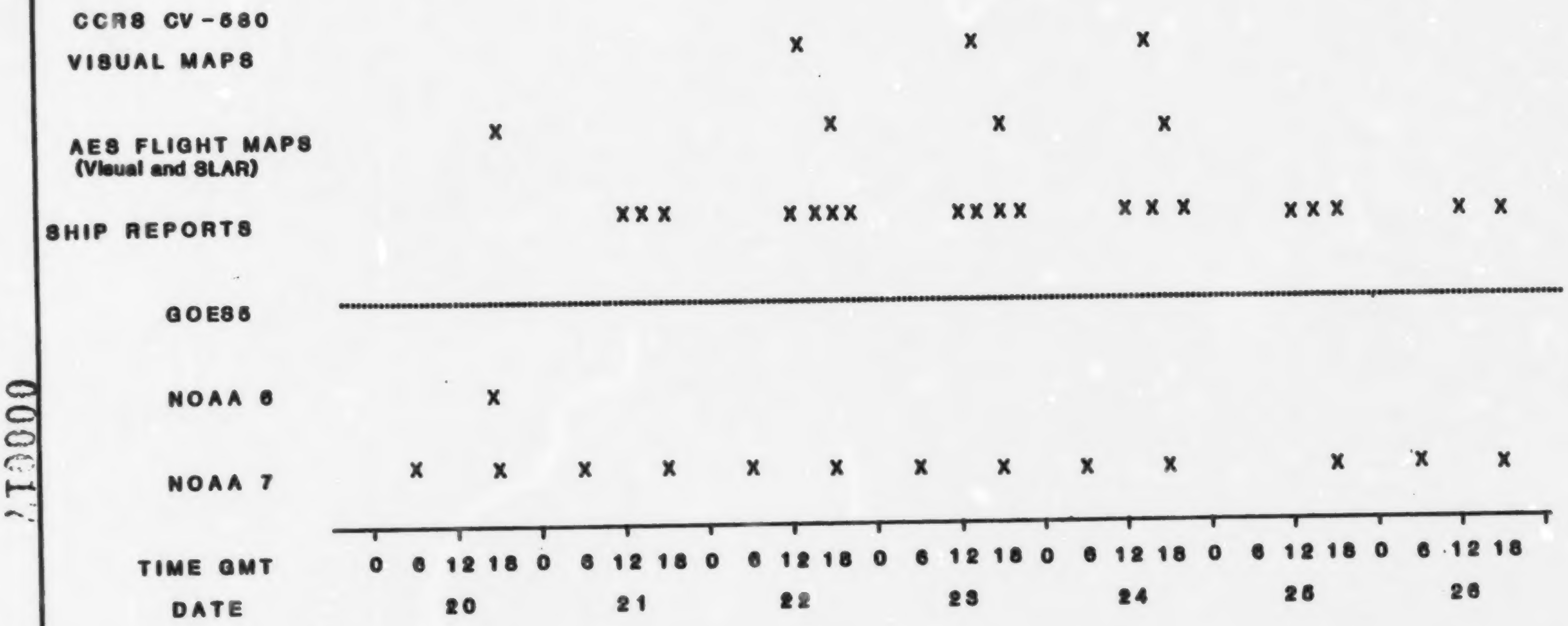

FIGURE 6 ICE DATA RECEIVED DURING THE PROJECT

Table 1

Data Source	Information Provided
GOES imagery	- position of ice edge
NOAA imagery	- position of ice edge - some indication of the main ice type and concentration
AES SLAR maps	- the main and secondary ice types - the overall ice concentration in five categories
Visual flight maps (from AES and CCRS flights)	- ice type by tenths of coverage - tenths of floes > 100 m in diameter - tenths of ridging and rafting - position of some icebergs
CCRS SAR imagery	- not analyzed for project
Ships reports FRANKLIN	- same as visual maps plus ridge height and ice thickness

concentrations as the visual maps but the data are still adequate for this purpose. The main disadvantage of the AES SLAR maps is that they did not include iceberg or ridge information, however, this sensor is capable of providing some information on these parameters. The CCRS SAR was not used in an operational mode during this project and the only data collected were for a number of small test areas. Based on these data it appears that the direct readout from the SAR would enable an experienced interpreter to identify the ice type and concentrations and, in addition, would provide useful information on ridging and icebergs. The only significant operational disadvantage of the SAR is the large amount of data produced. During the experiment an operational analysis of ice conditions in a small area was attempted using the SAR data. This experiment indicated that the data produced by the SAR, for even a small area, cannot be analyzed on the aircraft and requires several hours to analyze after the flight. The amount of data produced can be reduced by increasing the scale or reducing the data quality but this would reduce the effectiveness of the sensor for detecting icebergs. This is a problem that requires further attention when deciding between the use of a SLAR or SAR system in an operational program.

Using the 1:4 million scale NOAA imagery, the overall ice concentration and main ice type could be reliably estimated but the break down of ice concentration by ice type was generally less reliable. This type of analysis was, however considerably more reliable when there was some previous flight or ship data available. The satellite has the added advantage that larger scale patterns of ice cover, such as the large floes noted in Section 4.2, can be identified. Further work is required to determine what effect some of these features have on navigation. The 1:10 million scale NOAA imagery was generally less useful than the 1:4 million imagery but still provided a good indication of the overall ice concentration, while the GOES imagery was mainly used for identifying the position of the ice edge.

A subjective analysis of the data collected indicates that under the type of weather conditions experienced during this study, ice conditions can be adequately monitored using a combination of visual ice flights and satellite imagery. However, during a normal week there would be three or four days during which there would be no satellite coverage due to cloud conditions and at least two or three days during which visual airborne observing would be impossible due to poor visibility. Under these conditions a SLAR or SAR system would be required. Based on the ice type and concentration data required there appears to be little difference between the two systems. However, the requirement for data on ridging, icebergs and multi-year ice will be the main factor to consider when deciding on the system required. Evaluating the ability of these sensors to detect these hazards is outside the scope of study but the requirement for these types of data will be addressed further in Section 5.5.

5.3 Evaluation of Current Ice Analysis

The aim of the current ice analysis chart is to allow the Master of the vessel to evaluate current ice conditions in the study area prior to entering the pack. Based on his review of this chart he would decide to either use the recommended route shown on the chart or select his own route using the chart. The ice codes used in this chart are similar to those used by AES except that additional symbols are included to depict such features as areas of pressure and orientation of leads. The methodology used to prepare the current ice analysis charts is outlined in Section 3.3.

The evaluation of the current ice analysis charts was carried out by comparing them with the AES current ice charts and the observed ice charts. A comparison of ice concentrations shown on the NORDCO charts with the ice concentrations shown on the AES current ice charts (Table 2) indicates that the difference is generally one or two tenths with a slight tendency for the AES ice charts to show a higher ice concentration. This is not surprising considering the stable ice conditions and the good coverage during this period. The comparison between ice conditions shown on the two types of analysis charts and the observed charts indicates that the NORDCO analysis was generally

Table 2

Comparison of Ice Conditions Shown on the 1980 GMT NORDCO Current Ice Analysis Chart and the AES Current Ice Chart

		54N53W	54N54W	54N55W	54N56W	54N57W
MARCH 26	NORDCO	4321	4131	4131	711X	OW
	AES	5121	5121	6111	6111	2000
	Diff	1200	1010	2020	1001	2000
MARCH 25	NORDCO	4131	211X	620X	620X	442
	AES	5122	5122	6112	6112	X172
	Diff	1011	3012	0112	0112	0330
MARCH 24	NORDCO	4/10 S 342X	5122	6211	6211	X342
	AES	0026	5122	5122	6112	X172
	Diff		0000	1111	0101	0230
MARCH 23	NORDCO	4/10 S 342X	622X	811X	811X	81XX
	AES	4/10 S 343X	6121	6121	91XX	91XX
	Diff		0101	2011	1010	1000
MARCH 22	NORDCO	522X	522X	711X	811X	442
	AES	4/10 S 3421	5122	91XX	91XX	X019
	Diff		0102	2010	1010	0437
MARCH 21	NORDCO	5131	5131	71XX	71XX	343
	AES	5X11	7111	7111	5221	X64
	Diff	0120	2020	0011	2121	0321

NOTE In the difference column X indicates that the AES chart has a higher concentration closer to the observed conditions. This is a result of the following factors:

(a) due to communications problems the AES observed ice charts did not arrive in Ottawa in time to be included in the AES ice chart, however, they were included in the morning NORDCO charts;

(b) the AES analysis charts are at a large scale and, therefore they may not include some small areas shown on the observed charts; and

(c) the AES analysis chart often gives several ice codes for an area without showing the boundary between them, this makes it difficult to directly compare these charts with the observed charts.

Based on this review it appears that the analysis of ice types and concentrations shown on the NORDCO current ice charts represents the state-of-the-art.

A comparison of the extent of deformed ice reported on the different charts indicates that the NORDCO ice analysis generally reported one to three tenths of deformed ice which was slightly higher than the AES charts, slightly lower than the visual charts produced by the INTERA observer and very close to the ship reports. The AES current analysis charts generally do not report the extent of deformed ice. The method of coding the amount of deformed ice is an area that requires further attention since there is a considerable amount of variation in the extent of deformed ice reported by different observers.

A comparison of the amount of the pack composed of medium sized floes shown by the NORDCO ice analysis and the AES ice analysis indicates that while they generally agree for some area of the chart they disagree in others. This may be a result of the technique of combining areas which takes place in the AES charts. An analysis of the observed data incidates that there was considerable variation between the different sources and even from day to day for the same source which is surprising considering the stable ice conditions. This is an area where further analysis of the observing procedures is required.

The iceberg positions reported on the NORDCO analysis chart were based on those reported by the AES and INTERA ice observers. A comparison of the two types of charts indicates that there is almost no relationship between the position of icebergs sighted. In addition there was no relationship between the sightings on different days by the same source. The reasons for this have been noted in Section 4.3. In the NORDCO analysis the positions of the bergs reported were noted and kept on plot as long as possible, however, due to the uncertainty in the observing procedures, it is difficult to evaluate the accuracy of these positions.

5.4 Evaluation of the 12 Hour Ice Forecast

The static ice conditions experienced during the study period resulted in very little real change in ice conditions during any 12 hour period. The only areas where any significant changes took place were at the outer edge of the pack and in Grosswater Bay. Much of the change indicated for the main body of the pack was a result of apparent differences in the observed ice conditions caused by different observers and different observing techniques. This noise in the data would completely mask any real changes over a 12 hour period and therefore any detailed evaluation of the 12 hour forecast would be fruitless.

5.5 Evaluation of Recommended Routes

The recommended route included within the ice information package was designed to provide the safest and most economical route through the pack ice. The criteria used for selecting this route are outlined in Section 3.4. In general these criteria involved avoiding the types of ice conditions that would significantly reduce the speed of the vessel and avoiding ice conditions that would represent a potential hazard to the vessel.

To evaluate the economic savings involved in using the recommended route the NORDCO vessel ice transit model (Gill et al 1981) was used to give transit times for this route and a standard route. The standard route used extended due west from 54°20'N, 52°00'W to just north of George Island. The ship used for this evaluation was the M.V. Arctic which is an icebreaking bulk carrier. With open water conditions this vessel can transit the standard route in 12.4 hours. The transit times along the standard route and recommended route during the study period are shown in Table 3. The ice conditions experienced during the study period only increased the transit time along the standard route by an average of 20%. The reason for this small effect is the absence of any pressure situations since the transit times increase drastically when the ice is under pressure. Under these conditions the average time saved by using the recommended route was only 0.17 hours. If, however, the ice was under pressure the time saved by using the recommended route would increase since even a slight reduction in ice concentration has an important effect on transit times when the ice is under pressure. Under some pressure situations the ships would be delayed for days and if it could be routed around these situations the savings would be considerable. One additional factor that was not considered by the transit model is the effect of the large floes observed on the satellite imagery. The recommended route was often selected to avoid crossing these floes but the effect of these floes on navigation is not handled by the transit model.

Apart from the economic factors, the recommended route was selected to avoid ice hazards. Since there were no significant areas of multi-year ice in the study area, the only hazard considered was icebergs. In many cases the recommended route was selected to avoid high concentrations of icebergs (1930 GMT, March 23). Before this technique is used operationally the following two assumptions need to be investigated further. Is there a real difference in the iceberg concentration in these areas or is it simply a result of the observational techniques and what effect will these icebergs have on the safety of the vessel?

Table 3

Transit Times for M.V. Arctic Through Pack

Date	Time (GMT)	Recommended Route	Standard Route	Diff.
March 21	1230	14.50 hr	14.84 hr	+ 0.34
March 21	1930	13.95 hr	15.72 hr	+ 1.77
March 22	1230	15.15 hr	15.28 hr	+ 0.13
March 22	1930	15.58 hr	15.25 hr	- 0.33
March 23	1230	15.00 hr	14.71 hr	- 0.29
March 23	1930	15.47 hr	15.04 hr	- 0.43
March 24	1230	14.26 hr	14.44 hr	+ 0.18
March 24	1930	15.20 hr	15.12 hr	- 0.08
March 25	1230	15.17 hr	14.83 hr	- 0.34
March 25	1930	14.38 hr	14.75 hr	+ 0.37
March 20	1230	14.15 hr	14.45 hr	+ 0.30
March 26	1930	14.32 hr	14.68 hr	+ 0.36

In summary the recommended routes did not result in a significant reduction in the transit time but this conclusion might not be valid under different (more normal) operating conditions and further work is required on the effect of ice hazards, such as multi-year ice and icebergs, and their detection.

6.0 ALTERNATIVE VESSEL ICE MANAGEMENT SYSTEMS

6.1 Introduction

The vessel ice management system addressed in this report is based on using a private firm to provide conventional ice analysis, ice forecasting and ship routing services. This chapter will investigate two potential alternatives to this system. The first alternative is to use existing AES services or some upgraded version of these services and the second is to provide direct tactical support to the ship using real-time SLAR or SAR imagery.

6.2 The AES Alternative

At the present time AES issues one chart per day showing current ice conditions for the Eastern Canadian seaboard. This chart is at a scale of 1:2 million and is issued at 2000 GMT each day. In addition AES issues a general written ice forecast for Newfoundland waters.

The present AES service is not suitable for a vessel ice management service for the following reasons:

a) AES only issues one chart per day covering the study area but during periods of rapidly changing ice conditions this would not be sufficient. Data and changes in meteorological conditions could be incorporated if required.

b) The scale of the AES ice chart (1:2 million) does not allow ice conditions to be analysed in sufficient detail. In addition, due to the large area covered, the ice forecaster cannot spend sufficient time on one area.

c) AES does not issue a map of forecast ice conditions and the written forecast is too general for use in a vessel ice management system.

d) There is almost no iceberg information on the AES maps.

e) Due to the shift schedule at AES ice forecasting centre there is only a technician on duty in the evening and no staff on duty at night. A vessel ice management system would require 24 hour contact between the ship and ice forecasters.

Over the next 2-3 years a number of these problems may be eliminated due to changes underway in AES. For example AES expects to expand its service to include icebergs within the near future. In addition, if a regular shipping route was to be established into the Lake Melville area, then a special ice forecast might be issued for this area. However AES does not expect to increase the number of maps issued each day and no change is expected in the shift system at ice forecasting central (Personel Communications, W.E. Markham, Director Ice Branch, AES). Since a vessel ice management system would require that more than one ice chart be issued each day and that a forecaster be on duty whenever the vessel calls it does not appear practical to design a system based on AES services.

6.3 Direct Support

The other type of vessel ice management system considered was direct tactical support using a SLAR or SAR equipped aircraft. In this alternative the aircraft would cover the approaches to Lake Melville and then directly relay the imagery to the ship where it would be used to select a route.

The main disadvantage of this system is cost, since the SLAR or SAR equipped aircraft would have to be stationed in the area during the entire ice shipping season (8 months). If there was no other work for this aircraft the cost could exceed 1 million dollars. In addition the aircraft may not always be available to fly at the required time due to weather conditions at the base of operations.

This system will also be at a disadvantage during periods of rapidly changing ice conditions, such as during a storm. In these cases the data provided the ship may not provide a good indication of conditions that may occur several hours later. This system will therefore be most ineffective during storm situations when ice pressure situations are most likely to occur.

If, in the future, there is coverage of this area by radar equipped satellites a system of direct support may be practical. To provide this type of service the satellite would have to cover the area at least once every six hours.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This study has presented a description and evaluation of an operational demonstration of a vessel ice management system for Lake Melville and approaches. In general, the study achieved its objective of collecting the various types of observational data and producing an ice information package for the approaches to Lake Melville but due to the unusual weather conditions experienced during the study some aspects of the project could not be evaluated.

Based on the data collected it is apparent that under weather conditions similar to those experienced during this study the ice conditions can be adequately monitored by a combination of 1:4 million scale satellite imagery and visual ice flights, however, under normal conditions a SLAR or SAR capability would be required. In selecting between the two types of sensors the main operational factor to consider is the requirement for information on icebergs, multi-year ice and ridges. If this type of data is required the abilities of each of these sensors should be evaluated. An additional factor to be considered in any comparison is the capability to analyize the data collected within a reasonable time since the SAR system used in this study produced more data than could be used.

The analysis of the data collected appears to be state-of-the-art but the static ice conditions experienced precluded a test under more difficult conditions. The most important aspect of the project which could not be investigated was the analysis of ice pressure situations.

The analysis could be further improved by a better understanding of ocean currents in the study area and further research on the response of the ice cover in the study area to different wind conditions. A comparison of the NORDCO ice analysis with the AES current ice analysis indicates that the NORDCO charts included more types of data and more detail than the AES current ice analysis and the more frequent analysis allowed new data to be included much earlier. The ice analysis technique used is also considerably more cost effective than the other alternative which is using direct support by a private SLAR or SAR aircraft.

The feasibility of providing a 12 hour forecast map was investigated in this project but the static ice conditions experienced prevented a reasonable test of this product.

The recommended shipping route provided resulted in only a slightly reduced transit time but under different ice condition the results could be considerably different. The recommended route was also selected to reduce the hazard from icebergs but this criterion needs to be investigated further due to problems with identifying icebergs and a lack of data on the effect of icebergs on navigation.

7.2 Recommendations

1. Further research should be carried out on the ability of SLAR and SAR to detect ice hazarads, such as multi-year floes and icebergs.

2. The effect of weather conditions on the operation of remote sensing aircraft should be investigated.

3. The average number of days in each month that have cloud free conditions (satellite coverage) and the average number of days when visual ice observing can be used should be determined. This will allow a reliable estimate of the required number of radar flights.

4. An analysis of ocean currents in the study area should be carried out using existing unprocessed data.

5. A standard technique for coding ridge statistics should be developed.

6. The existing data base of satellite imagery and aerial observations should be analysed to further develop ice forecasting techniques.

7. The economic value of ship routing should be investigated further by using the vessel ice transit model in conjunction with existing observational charts.

8. The influence of the large floes seen on the satellite imagery on navigation should be investigated.

9. The influence of ice hazards on ship safety should be investigated. This would include an analysis of the value of routing around areas of high concentrations of icebergs and multi-year ice.

10. The requirements for communications between the forecasting office, ships and aircraft should be investigated.

11. Ships of opportunity, such as sealing vessels and Coast Guard icebreakers, should be used to collect ice data and test vessel routing services.

12. The ability of future radar equipped satellites to replace aircraft data should be investigated.

References

Bradford, D., Newfoundland - Mainland Transportation Study, Vol. 4, Pt. 2. "A Description of Operating Conditions affecting Navigation in the Gulf of St. Lawrence area". Prepared for Canadian Surface Transportation Administration, Ministry of Transport, Ottawa 1972.

Bradford, D., "Environmental Conditions Affecting Navigation in the Newfoundland - Labrador Coastal Area". Newfoundland Coastal Transportation Study Vol. 5. Prepared for Canadian Surface Transportation Administration, Ministry of Transport, Ottawa 1973.

Bradford, J.D., "Icebreaker Probes to Lake Melville, Labrador in 1972". Manuscript Report Series No. 54, Marine Science Directorate, Department of Fisheries and Oceans, Ottawa 1979.

Gill, R.J., A. Aboul-Azm, B.F. Terry, and W.E. Russel, "A Ship Transit Model for Passage through ice and its applications to the Labrador Area" paper presented at the Society of Naval Architects and Marine Engineers Spring Symposium Ottawa, 1981.

NORDCO Limited "Lake Melville/Offshore Labrador Year-round Navigation Study 1978-79" Report prepared for the Department of Industrial Development, Government of Newfoundland and Labrador, 1980.

A

APPENDIX A

Terms of Reference

REQUEST FOR PROPOSALS
FOR
VESSEL ICE MANAGEMENT SYSTEM
AN OPERATIONAL DEMONSTRATION

Department of Regional Economic Expansion

Government of Newfoundland
Department of Development

February 17, 1982

INTRODUCTION

The Department of Development of the Government of Newfoundland and Labrador is pursuing the problem of defining the technical feasibility, costs, and risks associated with winter long shipping into Lake Melville.

One component of this effort is the development of a Vessel Ice Management System which can provide accurate and timely ice information on safe and economical shipping routes.

While the various remote sensing systems under development present the potential to provide continuous, all weather information, there can be expensive and time consuming delays before the ideal system is achieved. It may well be that, with present operational (or near operational) capabilities, an acceptable system can be put in place.

The purpose of this exercise is to provide a demonstration of what can be achieved using available systems for: remote data collection; image production; analysis and interpretation; and communication.

STUDY OBJECTIVE

To illustrate the present operational capability to utilize remotely sensed data in providing ice information as though to a vessel in winter transit through the Labrador Pack Ice and across Lake Melville.

STUDY APPROACH

During the field study programs planned for Lake Melville and the Labrador Sea during March 1982, a number of remote sensing platforms will be operating in the region. This will provide an opportunity to illustrate, using the most readily available data products, the present operational capabilities of these devices to supply a Vessel Ice Management System.

The consultant will undertake to obtain access to useful information, analyze and interpret that information on a timely basis and produce information of a nature, quality, and quantity that can be communicated to a (hypothetical) commercial vessel which is enroute to a destination in Lake Melville. The test period should last 7 - 14 days.

Following this exercise and by availing of surface data available from any survey vessels (or other sources) operating in the region during the test period, an assessment will be carried out to examine the accuracy and utility of the Ice Management reports which had been produced.

Through this exercise it should prove possible to obtain a clear appreciation of the present utility, potential, and development needs of remote sensing systems as applied to a Vessel Ice Management System.

REPORTING REQUIREMENTS AND SUBMISSION SCHEDULE

Monthly progress reports will be provided by the consultant reporting on progress to date, noting any proposed program amendments, and documenting expenditures and comitments. At the discretion of the client, meetings may be held in addition to or in place of written reports.

Four copies of a draft final report will be submitted by May 31, 1982 (or such other date as may be agreed to by the client). Thirty days after receipt of the comments on the draft report and following suitable compliance with or rebuttal of these comments, the Contractor will provide Two hundred (200) copies of the final report. The Final Report will be prepared so that its contents can be successfully photocopied on a Xerox 9200 (or equivalent) photocopier.

The cover and title page of the Final Report shall be prepared in a format approved by the client, and shall contain appropriate acknowledgement of the sponsors.

The final report shall contain

- The Terms of Reference of the Study
- An Executive Summary of salient findings, recommendations and conclusions

- An Introduction detailing the background to, and the purpose and objectives of the Study
- A section describing the study participants and roles
- A section describing methods and equipment
- A presentation and analysis of results obtained
- An interpretative discussion of the findings
- A list of references
- An annexed chronology of field activities

All measurements will be expressed in metric (S.I.) units.

ANNEX II

PROPOSAL TO PROVIDE AN OPERATIONAL DEMONSTRATION OF A VESSEL ICE MANAGEMENT SYSTEM FOR LAKE MELVILLE AND APPROACHES

Submitted to: The Department of
Development
Government of Newfoundland
and Labrador

Submitted by: NORDCO Limited
P.O. Box 8833
St. John's, Nfld.

000043

File Ref.: 169-81P

NORDCO Limited
Newfoundland Oceans Research and Development Corporation
P. O. Box 8833, St. John's, Newfoundland, Canada, A1B 3T2, Telephone (709) 754-2401, Telex 016-4596

January 29, 1982

Mr. Ivan Palmer
Assistant Deputy Minister
Department of Development
Government of Newfoundland
and Labrador
Confederation Building
St. John's, Newfoundland

Dear Mr. Palmer:

Enclosed for your consideration is a proposal to provide an operational evaluation of a vessel ice management system for shipping into Lake Melville. We feel that the expertise and infrastructure that currently exists in the NORDCO Environmental Forecasting Office makes NORDCO the logical Newfoundland Company to operate a service of this type when regular shipping into Lake Melville becomes a reality. For the purpose of this demonstration project, NORDCO has sub-contracted part of the remote sensing interpretation work to an outside company but we feel that in any future operational system, NORDCO would be capable of operating the total system.

If you have any further questions on this proposal, please contact Mr. John Newell, the project manager, or the undersigned.

Yours very truly,

Frank D. Smith

Frank D. Smith
President and
Chief Executive Officer

FDS/slh
Encl.

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Appendix A - NORDCO Ice Bulletin for Lake Melville and Approaches

Appendix B - Resumes of Key Personnel

1.0 INTRODUCTION

The following proposal is submitted to the Department of Development, Government of Newfoundland and Labrador in response to a request for proposals for an operational demonstration of a vessel ice management system.

In this proposal NORDCO will demonstrate that it has the ability to operate an operational vessel ice management system which will incorporate the existing NORDCO Environmental Forecasting office plus additional inputs of remote sensing data. In addition NORDCO will carry out a detailed evaluation of the operational stage of the project to demonstrate the value of the system and outline ways to improve the service.

2.0 APPRECIATION OF WORK SCOPE

To meet the requirements of this study NORDCO proposes to set up an operational demonstration of a vessel ice management system for Lake Melville and approaches and then to carry out a detailed evaluation of this system to determine its effectiveness and ways to improve the system.

The operational demonstration will be set up to provide twice daily ice reports to a hypothetical commercial vessel which is enroute to a destination in Lake Melville. This system will incorporate observational data from all existing sources such as satellite imagery, government ice reconnaissance flights and ship reports and in addition will include inputs of SAR and other remote sensing data from the RADARSAT project. Since in any operational system observational data will seldom be available in real time the system proposed by NORDCO will include an ice forecasting service to update the ice conditions between observations. This ice forecasting service will be based on the expertise in the NORDCO Environmental Forecasting office.

After the operational stage of the project is completed NORDCO will carry out a detailed evaluation of the project. This evaluation will focus on three questions:

(a) How good was the observational data?
(b) How good was the updating (forecasting) of ice conditions between observations?
(c) What was the value of the routing service when compared with the use of a standard route?

The answers to these questions will indicate the value of the ice management system and ways the system can be improved.

3.0 PLAN OF ACTION

NORDCO will carry out the proposed study in three stages. The first will involve project preparation and will include the organization required prior to the project and a small study of available ice and other environmental information for the study area. The second stage of the project will be the operational stage in which the NORDCO environmental forecasting office will issue regular ice reports. The final stage will include an evaluation of the operational stage and the writing of the final report.

3.1 Project Preparation

Prior to carrying out an ice forecasting program in a new area it is advisable to become familiar with those characteristics of the area which will influence ice conditions. The primary aim of this preliminary study will be to identify any available information on environmental condition in the area, particularly currents and to analyze a number of case studies for which good ice and weather data are available.

3.2 Operational Stage

In this stage of the project the NORDCO environmental forecasting office will function as an operational ice and weather information center for the (hypothetial) ship. The following services will be provided on a regular basis twice per day at 0900 LST and 1600 LST:

(a) a general description of current weather conditions in the study area (synopsis) and a brief weather forecast for the next 24 hours;

(b) ice charts for the approaches to Lake Melville and Lake Melville showing conditions at the time of issue with particular emphasis on features that will effect shipping, such as areas of pressure or heavy ridging;

(c) a forecast chart showing ice conditions in the approaches to Lake Melville 12 hours from the time of issue of the bulletin and

(d) a written description of a recommended route for a ship traversing the pack with a description of ice conditions that will be encountered along that route.

An example of a completed ice report is provided in Appendix A.

Due to the special nature of this project the ice reports will not be transmitted to a ship but will be sent daily to the Department of Development office in St. John's. If the client requires data transmitted to a ship there will be an extra communications charge.

The ice briefings described above will be prepared at NORDCO's environmental forecasting office in St. John's. This office operates 24 hours per day providing weather forecasting and ice forecasting services to a number of oil companies. The ice forecast will be handled by the project manager for this study who will prepare all the regular briefings. The weather forecast will be prepared in conjunction with the duty weather forecaster.

The following imput data will be used to prepare the ice briefing:

(a) Satellite Imagery

The NORDCO weather office has a direct link with the AES satellite data lab and receives all the NOAA and GOES imagery that is transmitted on that circuit. The imagery is printed on a K560 photocopier and is of photographic quality (Figures 1-3). The quality of this imagery is upgraded by the special techniques that the satellite data lab uses to enhance the imagery for identification of ice features. All the imagery is received in real time with NOAA imagery available four times per day and GOES imagery available every half hour. Both visual and infrared imagery is received. For the proposed project NORDCO will request that detailed enlargements of imagery for the study area be produced.

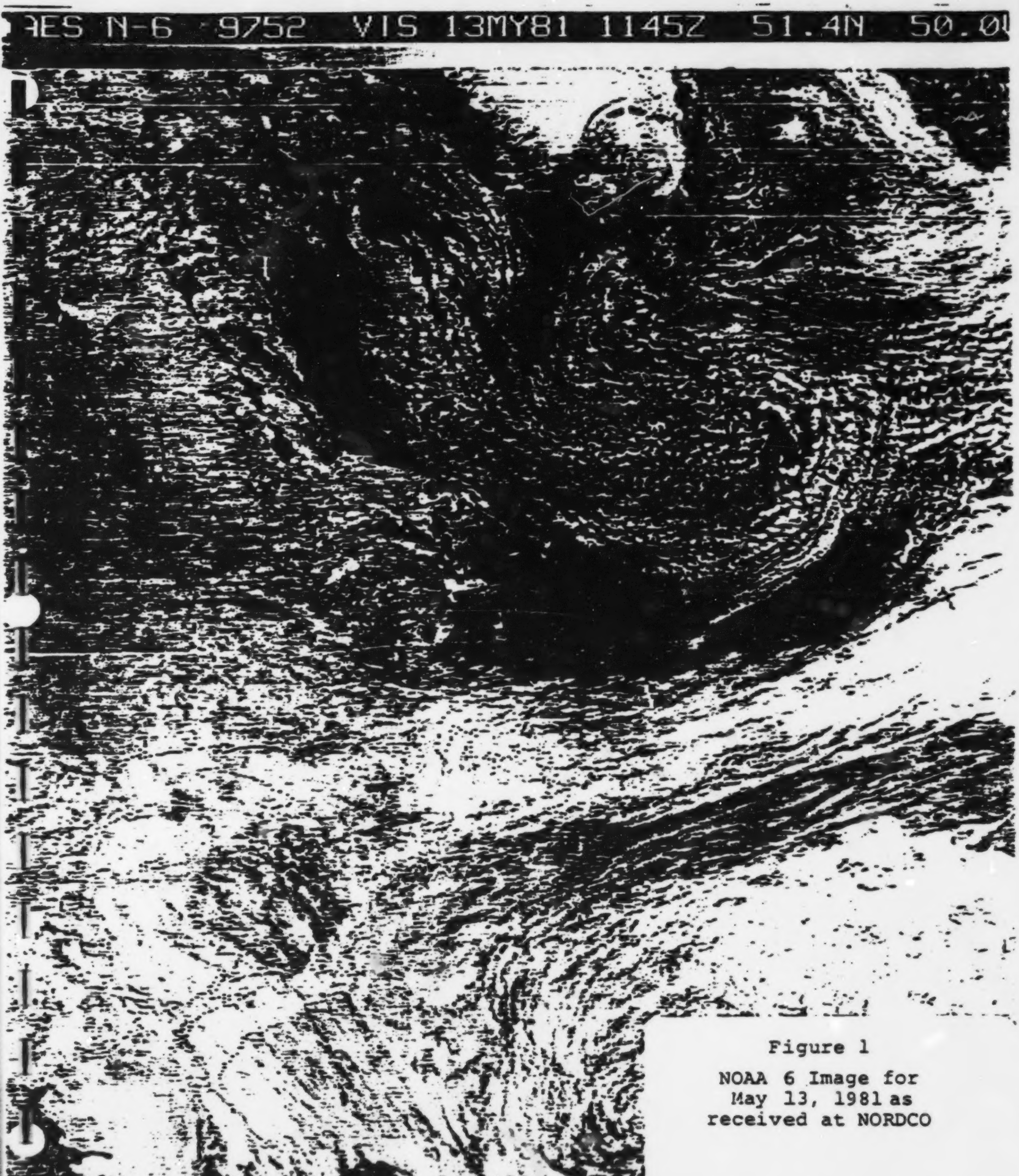

AES N-6 9752 VIS 13MY81 1145Z 51.4N 50.0

Figure 1

NOAA 6 Image for
May 13, 1981 as
received at NORDCO

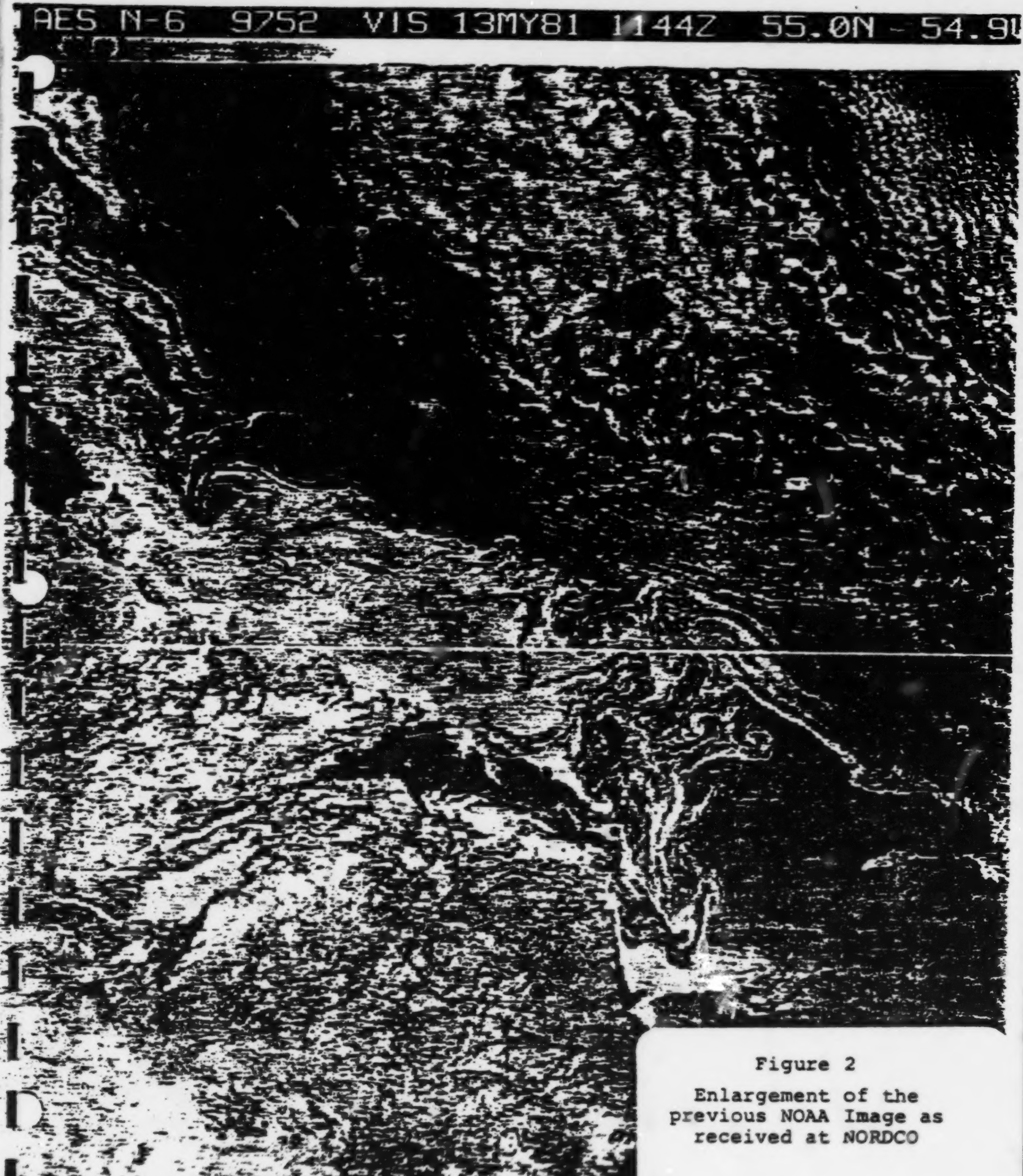

AES N-6 9752 VIS 13MY81 1144Z 55.0N 54.9

Figure 2

Enlargement of the previous NOAA Image as received at NORDCO

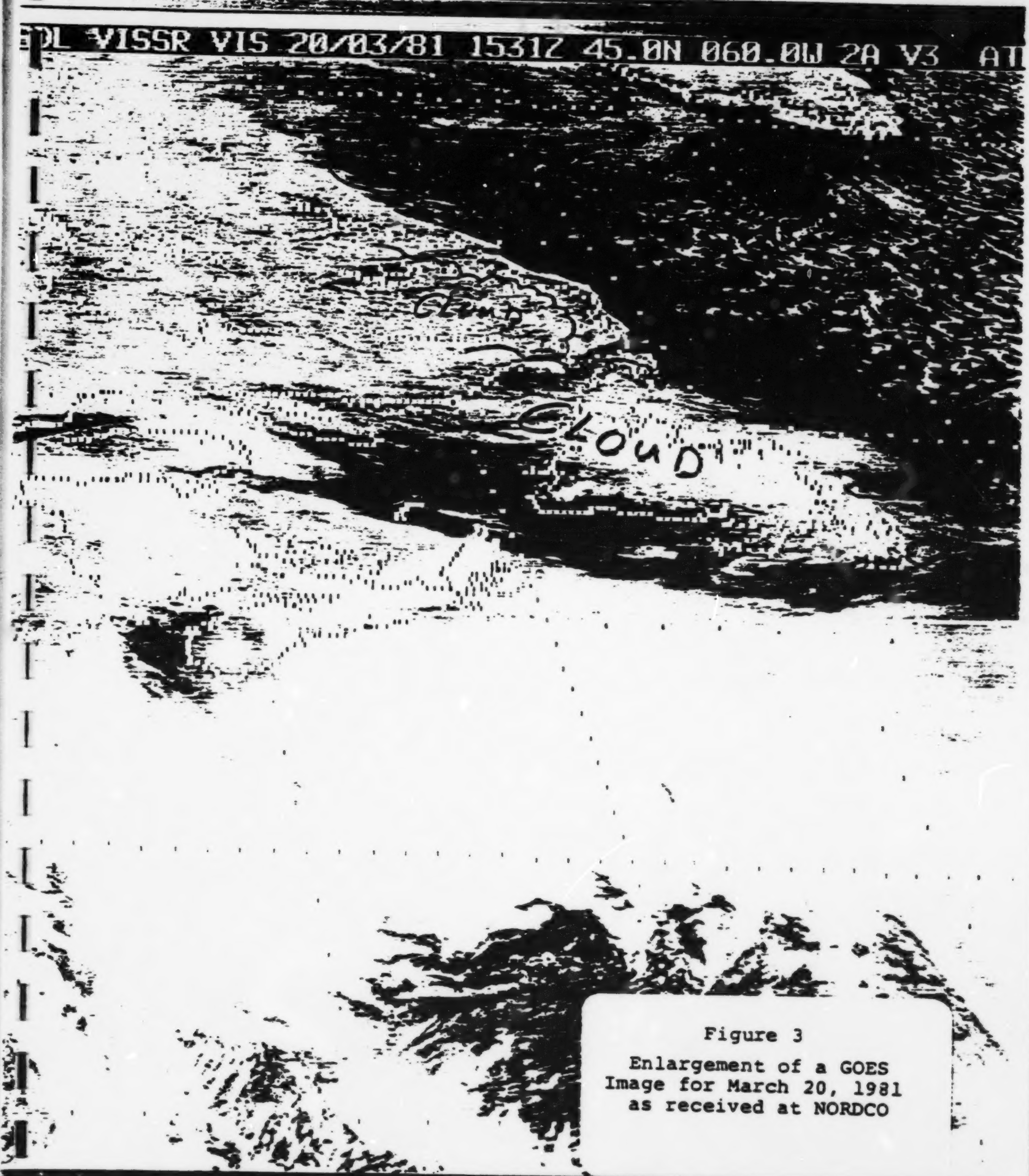

GOL VISSR VIS 20/03/81 1531Z 45.0N 060.0W 2A V3 AT
Clump
CLOUD

Figure 3

Enlargement of a GOES Image for March 20, 1981 as received at NORDCO

NORDCO will use the Shoe Cove Satellite Station as a back up source of NOAA imagery and a source of LANDSAT data.

(b) RADSARSAT Data

NORDCO will place an experienced SAR and SLAR interpreter in Goose Bay for the duration of the field program. This individual will collect all the remote sensing data and any visual data from the aircraft when they land and interpret this data. He will then transmit a completed ice analysis for the flight area to the NORDCO Environmental Forecasting office via telecopier. NORDCO will use a sub-contractor for this stage of the project. In any future operational project NORDCO envisages that this interpretation will be carried out on the aircraft by the operator.

(c) AES Flight Maps

NORDCO now receives AES data via the AES fax circuits but for this project we will arrange to receive this data directly from Gander. Since the AES SLAR data is incorporated directly into the flight map there is no requirement to reanalyze this data.

(d) Ice Reports from Shipping

For the study vessel NORDCO will arrange to receive regular ice and weather reports including data from helicopter flights. Data from other ships in the area will be received at NORDCO via the regular AES circuits.

(e) Ice Central Data

NORDCO receives all daily ice maps and forecast issued by ice central, Ottawa. This data will be used for comparison with the NORDCO analysis.

Since ice conditions can change rapidly the data received from these sources must be continually updated to reflect the new conditions. Prior to the time of issue of the ice bulletin all the ice information that has been received up to that time will be used to construct an ice chart showing present ice conditions. This chart will then be used, in conjunction with the weather forecast, to determine what changes in ice conditions will take place during the passage of the vessel. Using this information a recommended route will be established and the ice conditions along that route will be documented.

3.3 Project Evaluation and Report Writing

At the end of the operational stage of the project a detailed evaluation of the ice information service will be carried out. The aims of this evaluation will be to:

(a) compare the original analyzed ice conditions with any new data available after the end of the operational stage,

(b) compare the ice forecast with observed conditions and explain any discrepanceis and

(c) compare ice conditions along the recommended route with ice conditions along a standard direct route.

The comparison of the original analyzed maps with new data such as the recorded SAR data and data collected on the ship will give an indication of the accuracy of the original analyses. This will indicate if the real time outputs of the remote sensing systems are sufficient for operational use.

By comparing the forecasting ice conditions with the analyzed ice conditions for the same period the reliability of the ice forecast can be determined. In cases where there are significant differences between the two ice conditions the reasons for these differences will be identified. Special emphasis will be placed on identifying ways in which the present system can be improved.

The comparison of ice conditions along the recommended route with ice conditions along a standard route will indicate the value of a ship routing system over using a standard entry route. This comparison will focus on factors that are critical to vessel movement such as pressure situations, ridging, occurrence of icebergs and the occurrence of high concentrations of heavy ice. The results of this comparison could form the basis for a later evaluation of the economics of ship routing.

The final report for the project will outline the results of the project evaluation and in addition make a series of recommendations for improving the service.

4.0 PROJECT ORGANIZATION

NORDCO Limited will be the prime contractor on this study and will be responsible for all work carried out including any work carried out by sub-contractors. Mr. John Newell will be the project manager for the study and will also be the principal ice analyst. The duty forcasters in the NORDCO weather office will also be involved in the ice forecasting duties and will provide meteorological input into all the ice forecast. The duty technician in the NORDCO weather office will be responsible for some of the data handling for this project. INTERA Ltd. will provide the remote sensing specialist who will be stationed in Goose Bay during the operational part of the project and will aid in the later analysis of the SAR data. This company will act as a sub-contractor to NORDCO.

A time schedule for the project is shown in Figure 4. NORDCO will provide the client with four draft copies of the final report by May 31, 1982 and 200 copies of the final report 30 days after that date.

Figure 4

Project Schedule

```
Project Preparation    XXXXX

Operational Stage            XXXX

Project Evaluation                XXXXXXXXXXXX

Report Writing                              XXXXXXXXX

                     | FEB   | MAR   | APRIL  | MAY     | JUNE   |
```

5.0 MANPOWER ASSIGNMENTS

Name	Position
John Newell	Project Manager/Ice Analyst
Mike Hewson	Chief Meteorologist
John Crawford	Remote Sensing Specialist

Mr. Newell has been with NORDCO for the past six years. In that time he has acted as ice analyst on most NORDCO projects dealing with ice climatology and ice forecasting and as project manager for many of these projects. In addition Mr. Newell has pratical field experience dealing with sea ice in both the Labrador Sea and Beaufort Sea.

Mr. Hewson is the Chief Meteorologist responsible for the NORDCO weather forecasting office. Mr. Hewson has over eleven years experience in weather forecasting. For the duration of this project Mr. Hewson will be responsible for the operation of the NORDCO weather office.

Mr. Crawford is a staff consultant with INTERA Limited in Ottawa. He has a number of years experience in interpretating SLAR and SAR imagery of sea ice and has managed a number of projects dealing with the use of SLAR and SAR data for ship routing through ice.

Resumes of all personnel involved in this project are included in Appendix B.

6.0 CORPORATE EXPERIENCE

The following is a brief list of some of the related projects that NORDCO has carried out in the past.

TITLE	CLIENT	SUMMARY
Ice Management at an Arctic LNG Terminal	Acres Consulting Services Limited	Investigation of various ice management techniques for control of ice growth at an Arctic terminal
Lake Melville/ Offshore Labrador Year-Round Navigation Study	Government of Newfoundland and Labrador	Two-year program involving icebreaker probes and field surveys to determine the problems associated with year-round navigation into Lake Melville
Sea Ice/Iceberg Study for Grand Banks	Mobil Oil Canada Limited	A study documenting the sea ice/icebergs climatology of the Grand Banks providing an overview of the state of knowledge in specific areas of ice engineering
Shorefast Ice Study	Canadian Marine Drilling Company Limited	Ice management study to define methods for the maintenance of open water conditions for year-round drilling operations in the Arctic.
Ice Relief Study	Total Eastcan Exploration Limited	Interpretation of Atmospheric Environment Service laser profilometry data to define statistics of ice ridging in the Labrador Sea

Ice Forecasting, Cabot Strait	CN Marine	An operational ice forecasting service in support of ferry operations
Ice Forecasting Center	Mobil Oil	An operational sea ice/iceberg forecasting program for the Grand Banks
East Greeland Study	Hudson Bay Oil and Gas	A study of sea ice, climate and wave conditions for East Greeland
Long Range Ice Forecasting	BP Canada	A series of long range ice forecast for the Labrador coast
Sea Ice Conditions in Sydney Bight	DEVCO	A study of the ice climatology of Sidney Bight and its effect on the use of the port as an offshore supply base
Preliminary Environmental Assessment	Petro-Canada Exploration Limited	Comprehensive review of scientific reports on the Labrador Sea including sea ice and iceberg conditions
Weather Forecasting Service, Flemish Pass (1979)	Esso Resources (Canada) Limited	Provision of an operational forecasting service to support offshore drilling operations and vessel movements

Weather Forecasting Service, Northeast Coast of Newfoundland	British Petroleum Exploration Limited	Provision of forecasting services to support offshore drilling operations
Weather Forecasting Service(1980 and 1981)	Mobil Oil Canada Limited	Operational site specific weather, ice and sea state forecasting to support drilling in Hibernia area
Weather Forecasting Services, Labrador Coast (1980 and 1981)	Petro-Canada	Provision of an operational forecasting service to support offshore drilling operations
Weather Forecasting Services, Labrador Coast (1980)	Chevron Standard Limited	Provision of an operational forecasting service to support offshore drilling operations

Appendix A

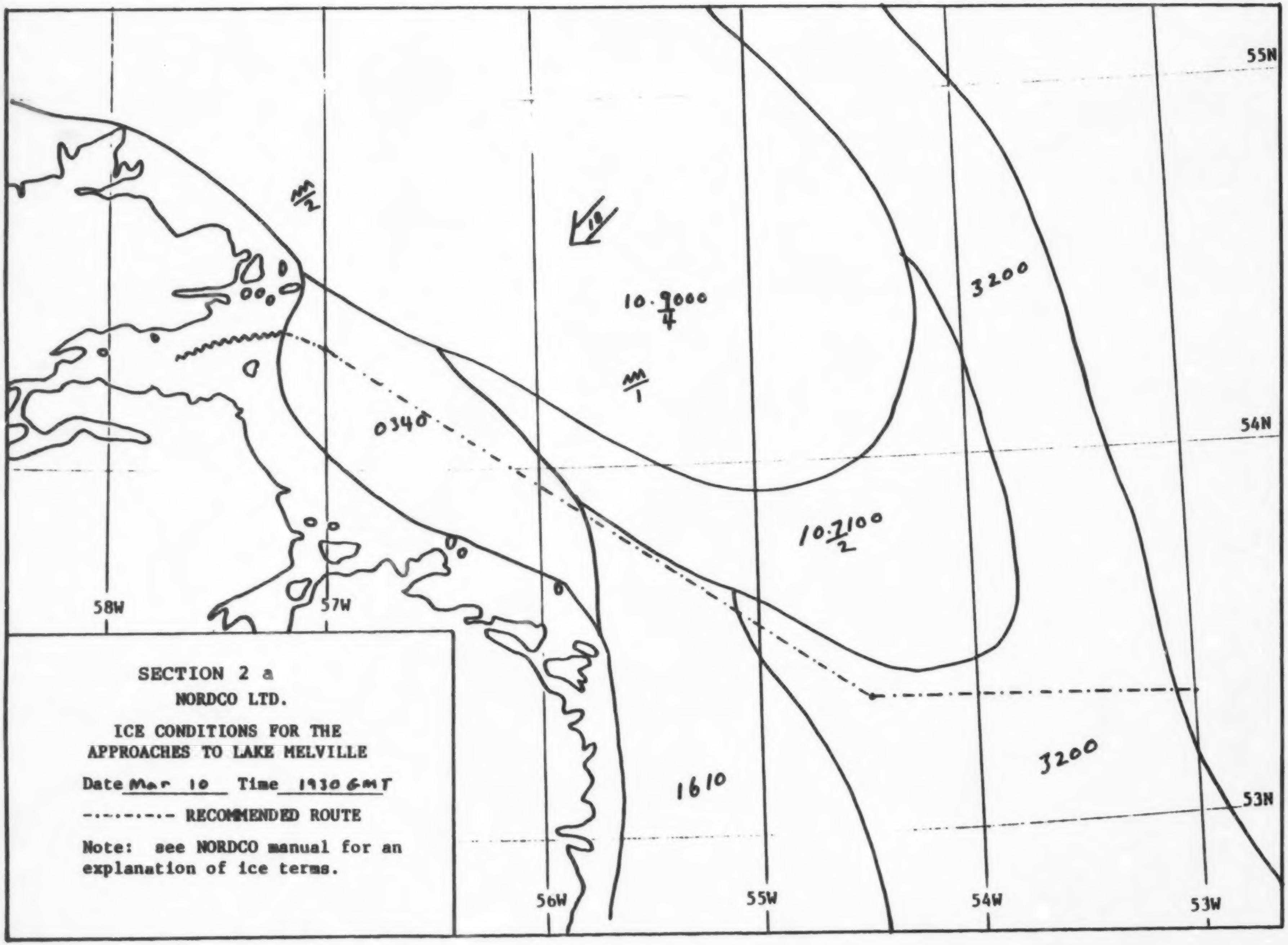
NORDCO LIMITED ICE BULLENTIN FOR LAKE MELVILLE AND APPROACHES

Section 1	Weather Conditions
Section 2 a	Current ice conditions in the approaches to Lake Melville
2 b	Current ice conditions in Lake Melville
Section 3	12 hour forecast of ice conditions
Section 4	Recommended route

SECTION 1 WEATHER CONDITIONS

WEATHER SUMMARY ISSUED FOR THE APPROACHES TO LAKE MELVILLE AT 1600 NST (1930 GMT), MARCH 10, 1982.

At forecast time a low pressure system centered in the Strait of Belle Isle was giving gale force northeasterly winds over the forecast area. This low is forecast to move northeasterly and be centered near 57°N, 49°W by 1200 GMT on the 11th. As the low moves away winds over the areas will gradually back to northwesterly and remain at gale force. The low is expected to remain stationary from 1200 GMT on the 11th to 0000 GMT on the 12th and winds will remain northwesterly but decrease to near 25 kts by the end of the period.


55N
54N
53N
58W
57W
56W
55W
54W
53W
3200
3200
10·9000/4
10·7100/2
0340
1610
m/1
m/2
10

SECTION 2 a

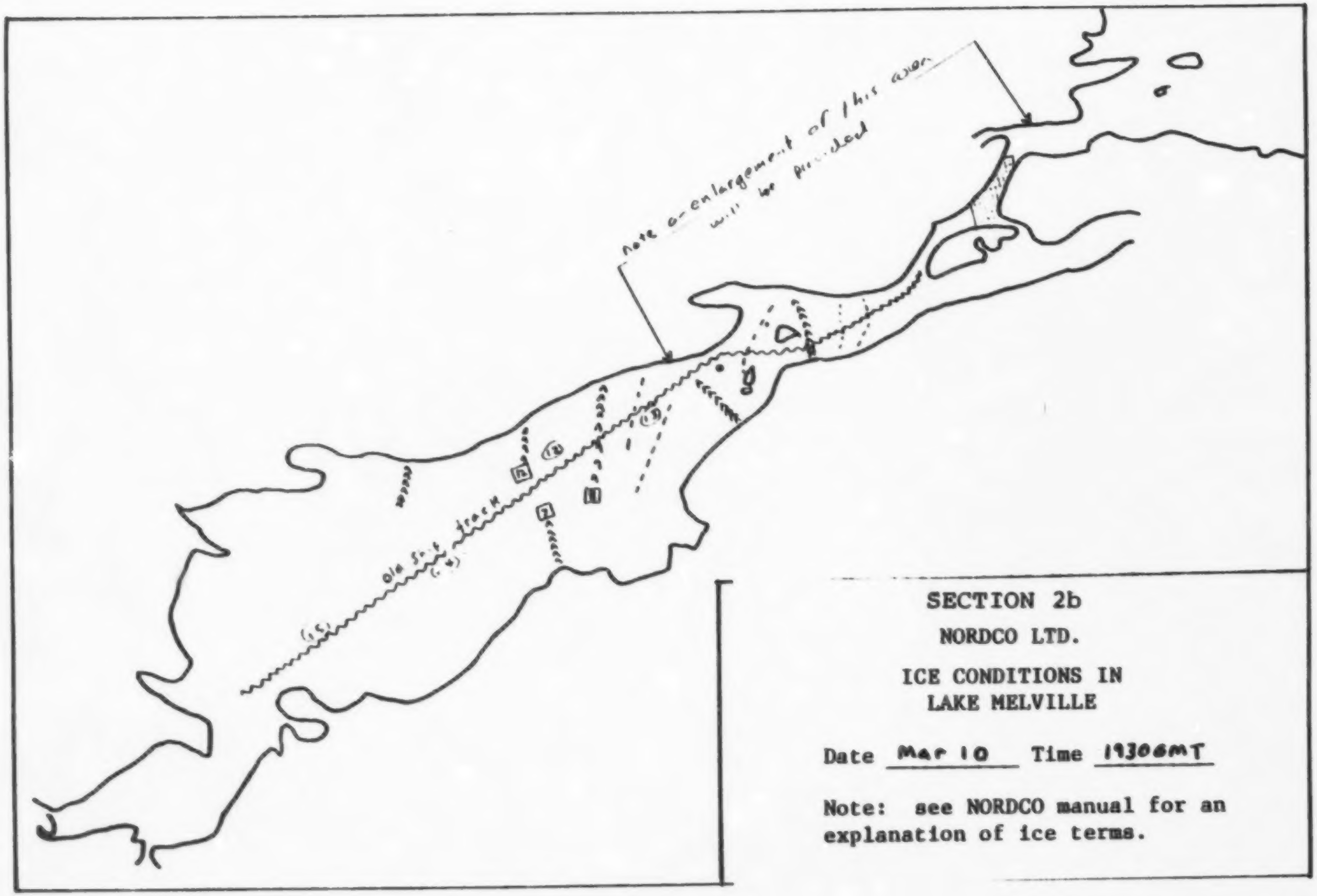
NORDCO LTD.

ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE

Date Mar 10 Time 1930 GMT

-·-·-·-·- RECOMMENDED ROUTE

Note: see NORDCO manual for an explanation of ice terms.


note – enlargement of this area
will be provided
old S.s.t track
(15)
(14)
(13)

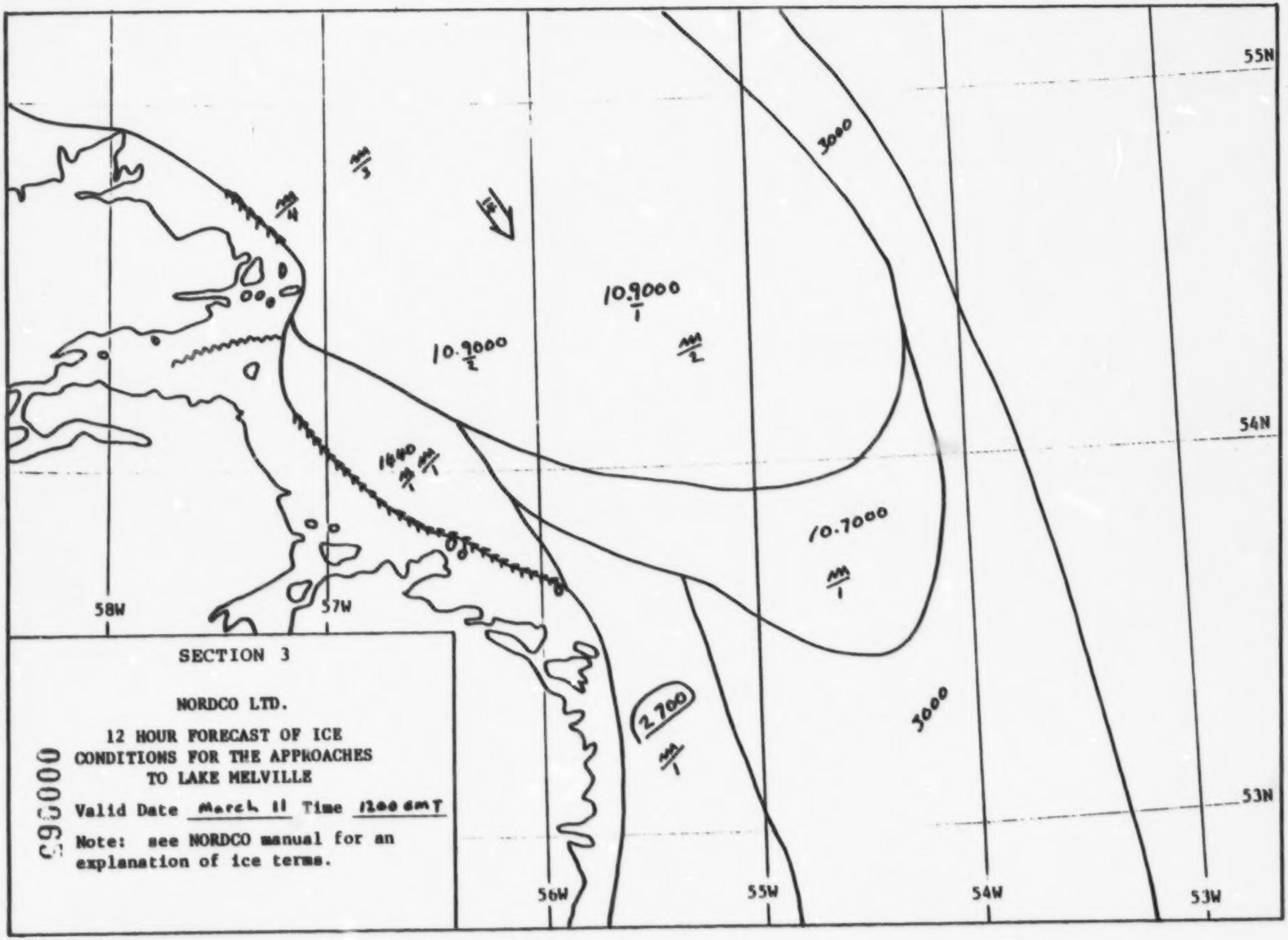
SECTION 2b

NORDCO LTD.

ICE CONDITIONS IN
LAKE MELVILLE

Date Mar 10 Time 1930GMT

Note: see NORDCO manual for an explanation of ice terms.


55N
54N
53N
58W
57W
56W
55W
54W
53W
3000
10.9000/1
10.9000/2
10.7000
1040
2700
3000

SECTION 3

NORDCO LTD.

12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE

Valid Date March 11 Time 1200 GMT

Note: see NORDCO manual for an explanation of ice terms.

000063

SECTION 4 RECOMMENDED ROUTE

The recommended route extends from 53°20'N, 53°00'W then east to 53°22'N, 54°30'W then northwest to 54°20'N, 57°00'W then along the standard shipping route into the lake.

From 53°20'N, 53°00'W to 53°22, 54°34'W the ice will be mainly 3 tenths first year and 2 tenths grey white. Floe size will be under 100 m in direction and there will be little ridging from 53°22'N, 54°30'W to 53°36'N, 55°09'W the same ice conditions will be encountered. From 53°36'N, 55°09'W to 53°54'N, 55°46'W the pack will be composed of 1 tenth of first year, 6 tenths of grey white and 1 tenth of grey ice. This 10 will be composed of mainly small floes with little ridging. From 53°54'N, 55°46'W to 54°20'N, 57°00'W the ice will be mainly 3 tenths grey white ice and 4 tenths grey ice.

B

APPENDIX B

Ice Information Packages

Issued by NORDCO Limited

March 21-26, 1982

Note: The key for interpreting the ice charts is provided at the end of this appendix.

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1230 GMT, Sunday, March 21, 1982

Weather Summary

At Forecast time a high pressure system was centered over Northern Labrador. This system was giving light northerly and calm winds over the area. Winds are Forecast to remain light for the next 24 hours.

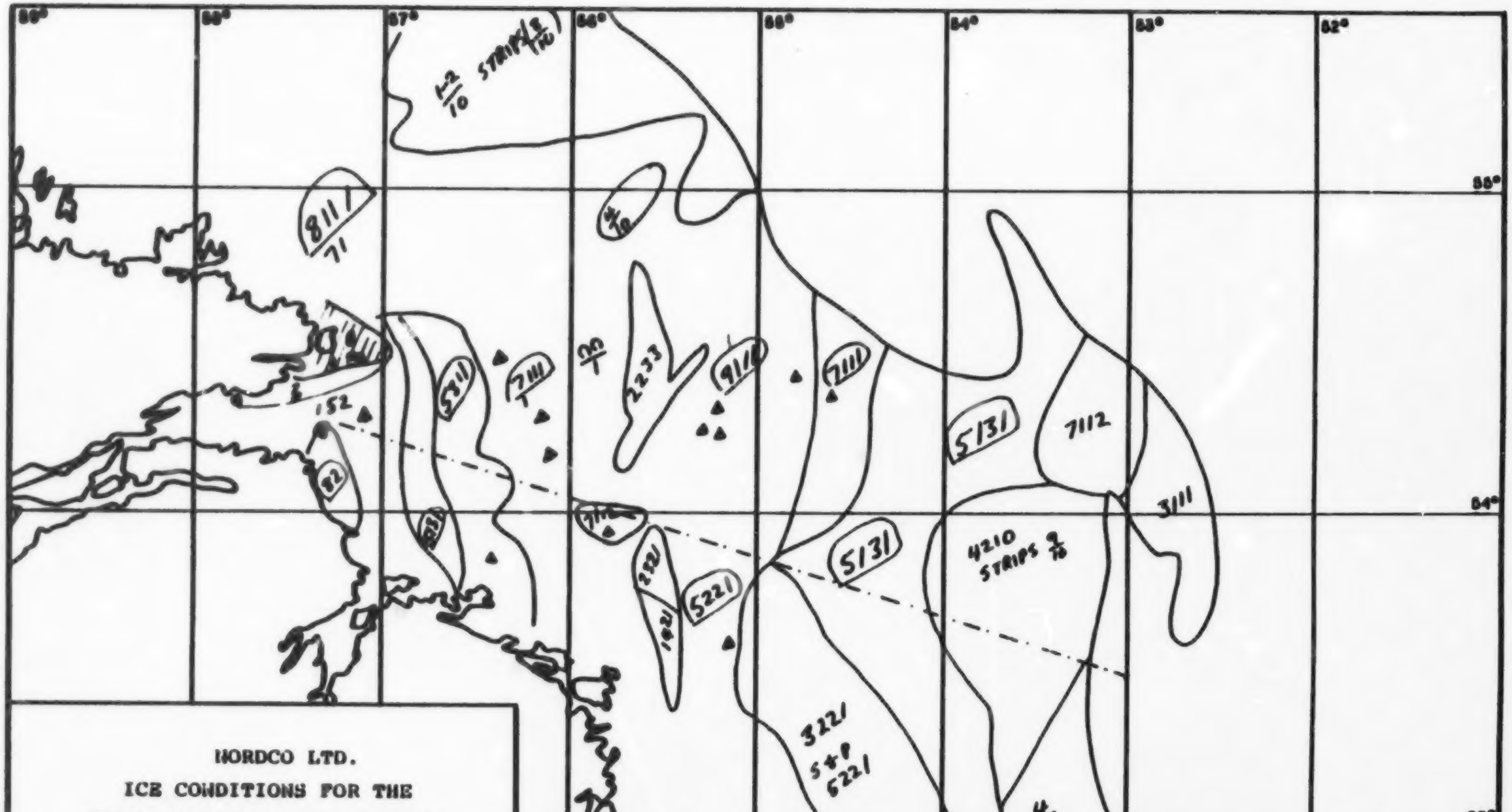
Recommended Route

The recommended route extends from 53°29'N, 53°W to just north of George Is.

From 53°29'N, 53°W to 54°03 W there will be 7/10 coverage with 4/10 first year ice, from 54°03W to 54°55'W there will be 9+/10 coverage with 5/10 first year ice, from 54°55'W to 56°20'W there will be 9+/10 coverage with from 5/10 to 7/10 first year ice, from 56°20'W to 56°53'W there will be 9+/10 coverage with 5/10 first year ice and from 56°53'W to George Island there will be 8/10 coverage of mainly new and grey ice. Between 56°W and 56°20'W there will be areas of hummocked ice.

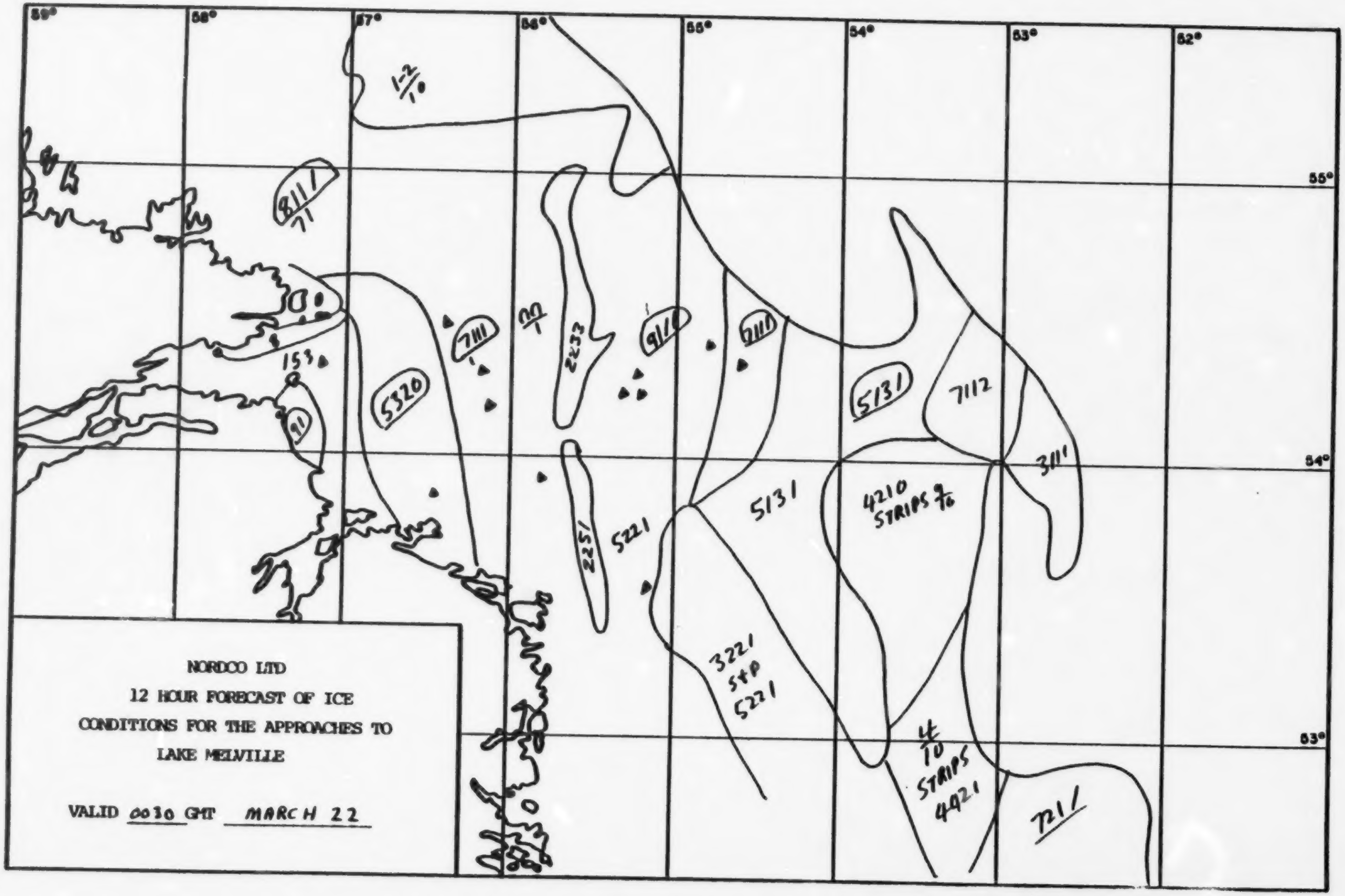
Data Base

Todays map is based on an AES flight map for the 20th, Satellite imagery for 1730Z March 20 and partial satellite coverage for 0730Z March 21. The last AES analysis did not include the data from the AES flight on the 20th.


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
1-2/10 STRIPS 8/10
8111/71
4/10
3/10
2233
9116
7111
5311
7111
152
82
5311
7116
2221
1021
5221
5131
5131
7112
3111
4210 STRIPS 9/10
3221 S+P 6221
4/10 STRIPS 4421
7211

NORDCO LTD.
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1230 GMT MARCH 21

-·-·-·-· RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
1-2/10
811/71
00
153
91
5320
7111
3/10
2233
9116
7111
2251
5221
5131
5131
7112
3111
4210 STRIPS 9/10
3221 S+P 5221
4/10 STRIPS 4921
7211

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES TO
LAKE MELVILLE

VALID 0030 GMT MARCH 22

Ice and Weather Summary Issued for the Approached to Lake Melville at 1930 GMT, Sunday, March 21, 1982

Weather Summary

At forecast time a high pressure system was centered over Northern Labrador. This system was giving light Northwesterly winds over the forecast area. Winds are forecast to remain light northerly for the next 24 hours and temperatures will remain near -15°c to -20°c.

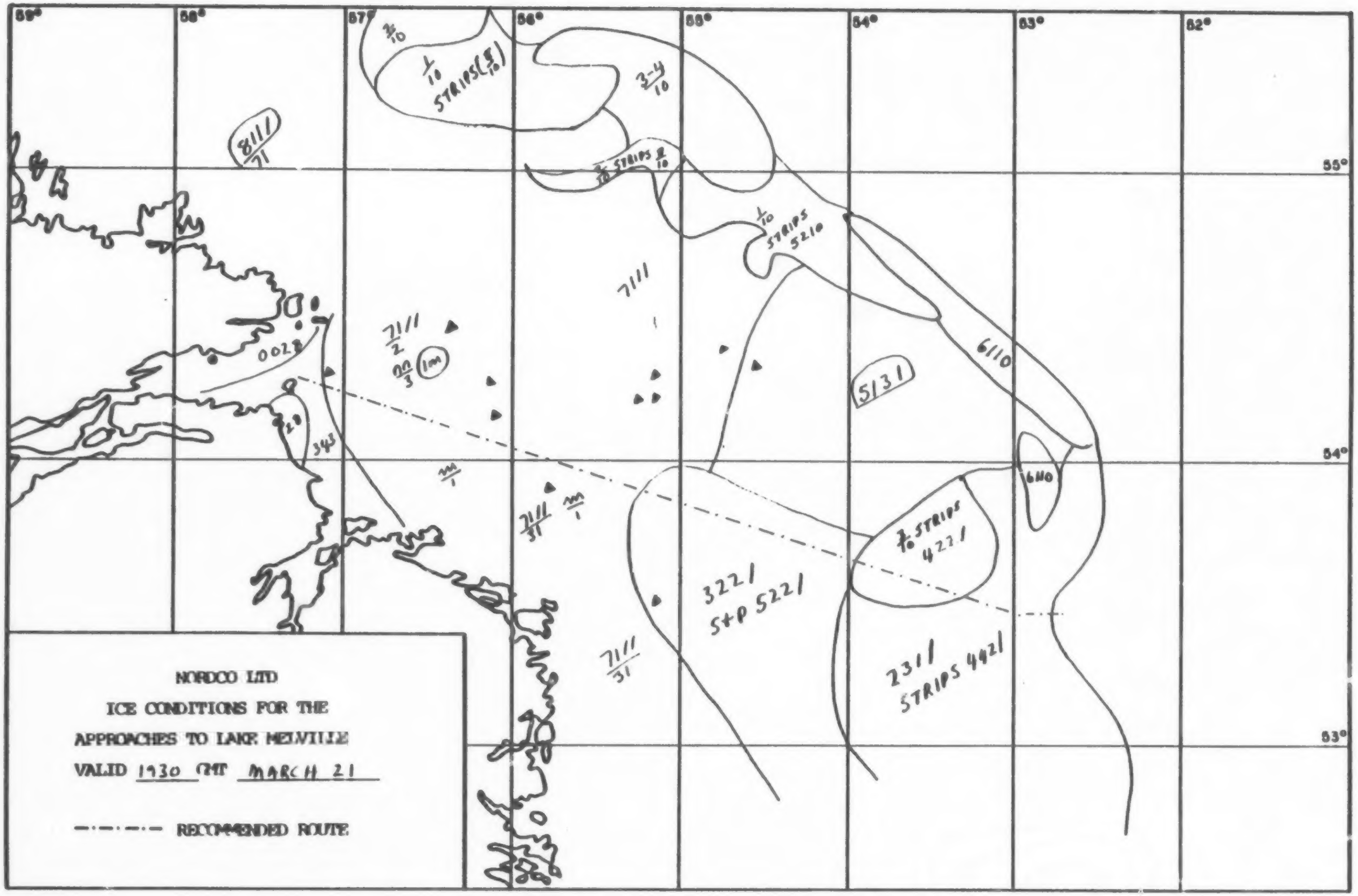
Recommended Route

The recommended route extends from 53°29'N, 52°40W to 53°40'W to 53°29'N, 53°W and then to just north of George Is.

From 53°29'N, 52°40'W, 53°W there will be 6/10 coverage with 2/10 first year ice, from 52°20'W to 53°55'W there will be 3/10 coverage in strips of 4221, from 53°55'W to 55°18'W there will be 7/10 coverage with 3/10 first year ice, from 55°18'W to 57°07'W there will be 8/10 coverage with 7/10 first year ice, west of 56°W this ice will be heavily ridged and hummocked. From 57°07'W to north of George Is. there will be 10/10 coverage of young and new ice.

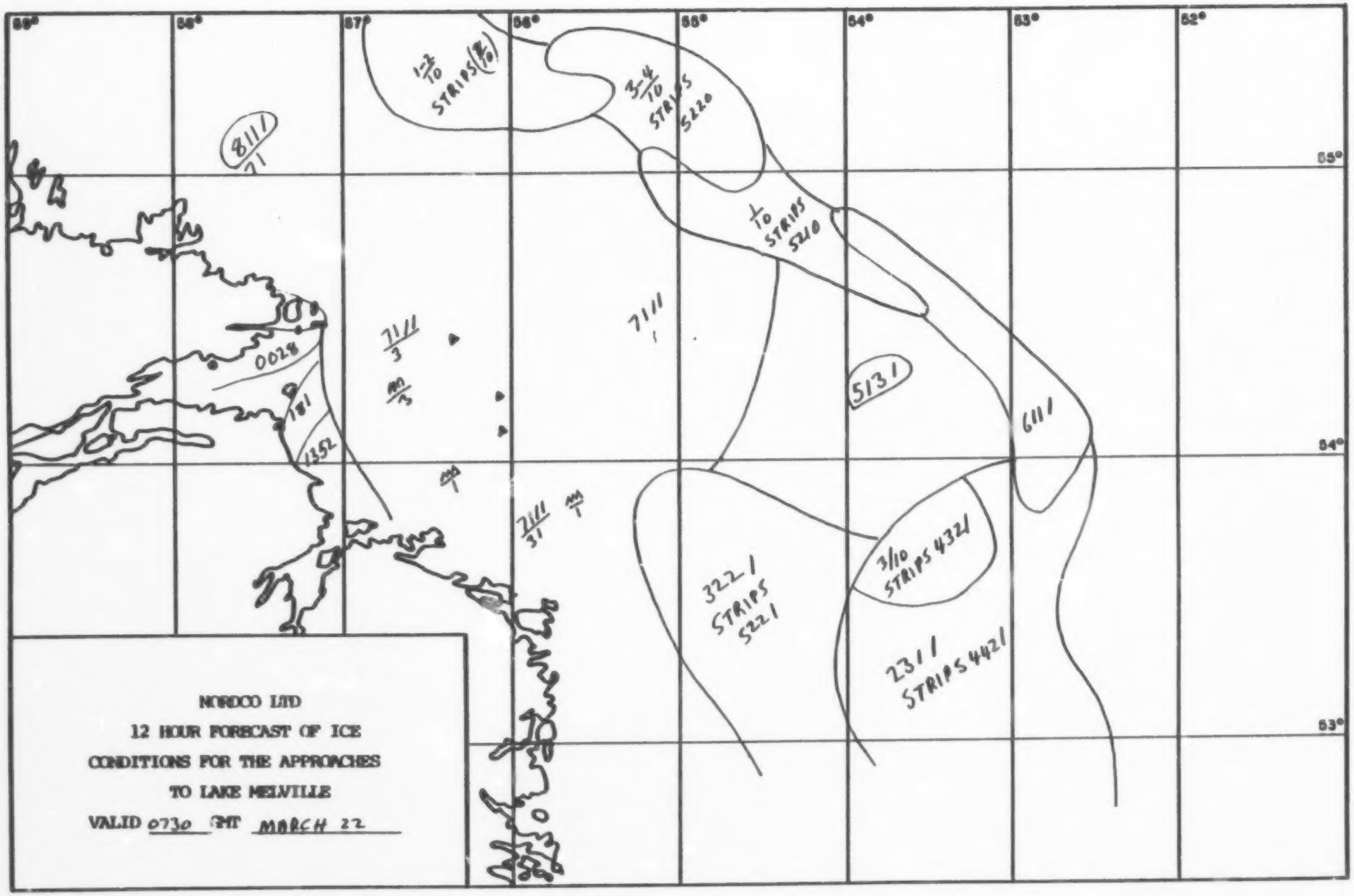
Data Base

This report is based on data from the previous analysis, satellite images for 1713Z, March 21 and reports from the Franklin for 12Z, 15Z and 18Z


59°
58°
57°
56°
55°
54°
53°
82°
55°
54°
53°
3/10
1/10 STRIPS (8/10)
3-4/10
8/11/71
1/10 STRIPS 8/10
1/10 STRIPS 5210
71/1
0028
71/1 2
m/3
1m
2/0
343
m/1
71/1 31
m/1
5131
6/10
6/10
1/10 STRIPS 4221
3221 S+P 5221
71/1 31
2311 STRIPS 4421

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1930 GMT MARCH 21

—·—·— RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
1-2/10 STRIPS (8/10)
3-4/10 STRIPS 5220
1/10 STRIPS 5210
8111/71
7111
7111/3
0028
181
1352
5131
6111
7111/31
322 1 STRIPS 5221
3/10 STRIPS 4321
2311 STRIPS 4421

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0730 GMT MARCH 22

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1230 GMT, Monday, March 22, 1982.

Weather Summary

At forecast time a high pressure system centered over Labrador was giving very light winds over the area. The winds are forecast to remain light and variable for the next 24 hours. Temperatures over the area will remain near -15 to -20°C.

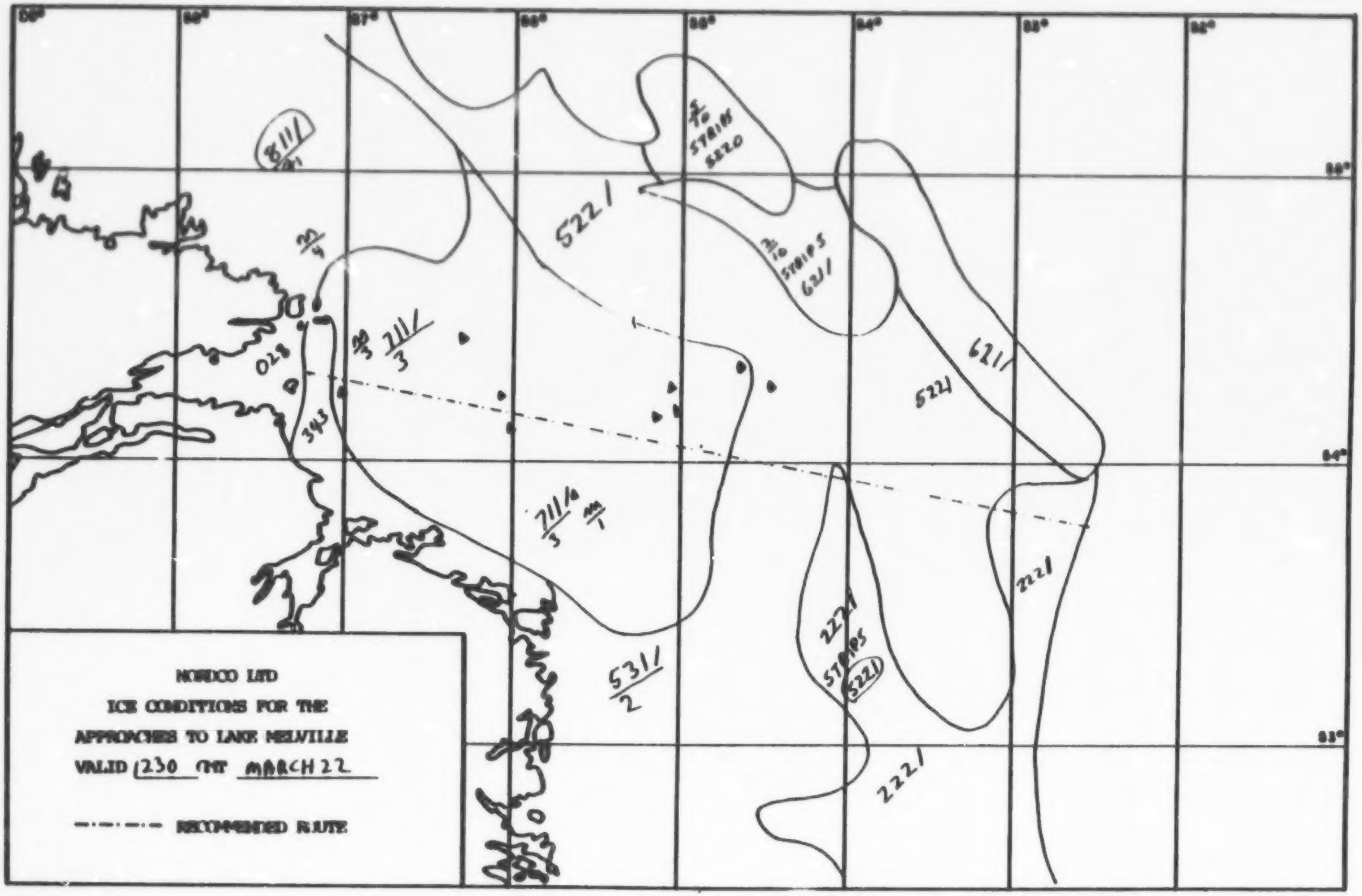
Recommended Route

The recommended route extends from $53^{\circ}46'$N, $52^{\circ}30'$W to just north of George Island.

From $53^{\circ}46'$N, $52^{\circ}30'$W to $53^{\circ}07'$W there will be 6/10 coverage with 2/10 of first year ice, from $53^{\circ}07'$W to $54^{\circ}45'$W there will be 9/10 coverage with 5/10 first year ice, from $54^{\circ}45'$W to $57^{\circ}04'$W there will be 9/10 coverage with 7/10 first year ice and from $57^{\circ}04'$W to $57^{\circ}13'$W there will be 10/10 coverage of young and new ice. Between $56^{\circ}20'$W and $57^{\circ}04'$W the ice is heavily ridged hummucked.

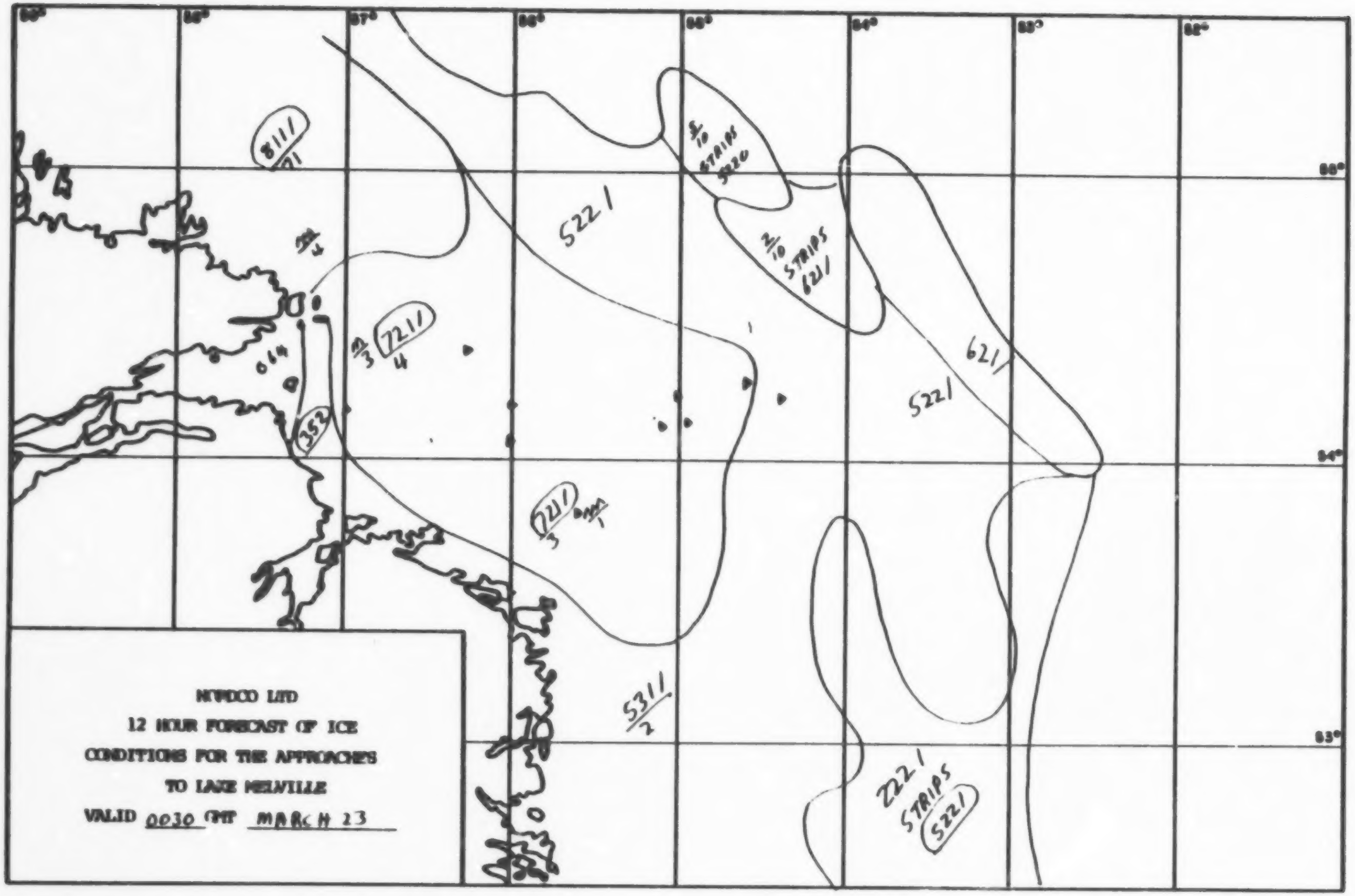
Data Base

Todays map is based on satellite imagery for 0713Z March 22, the previous report and the AES analyses for March 21.


8111
5221
STRIPS
5220
STRIPS
6211
028
343
711
3
711
3
6211
5221
2221
5311
2
2221
STRIPS
5221
2221

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1230 GMT MARCH 22

-·-·-·- RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
8111
21
7211
4
352
014
5221
3/10 STRIPS 5220
2/10 STRIPS 6211
621
5221
7211
3
5311
2
2221 STRIPS 5221

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0030 GMT MARCH 23

Ice and Weather Summary Issued for the Approaches to Lake Melville
at 1930 GMT, Monday, March 22, 1982

Weather Summary

At forecast time a high pressure system as centered over northern Labrador. This system was giving light and variable winds across the forecast area. Winds are forecast to remain light and variable for the next 24 hours.

Recommended Route

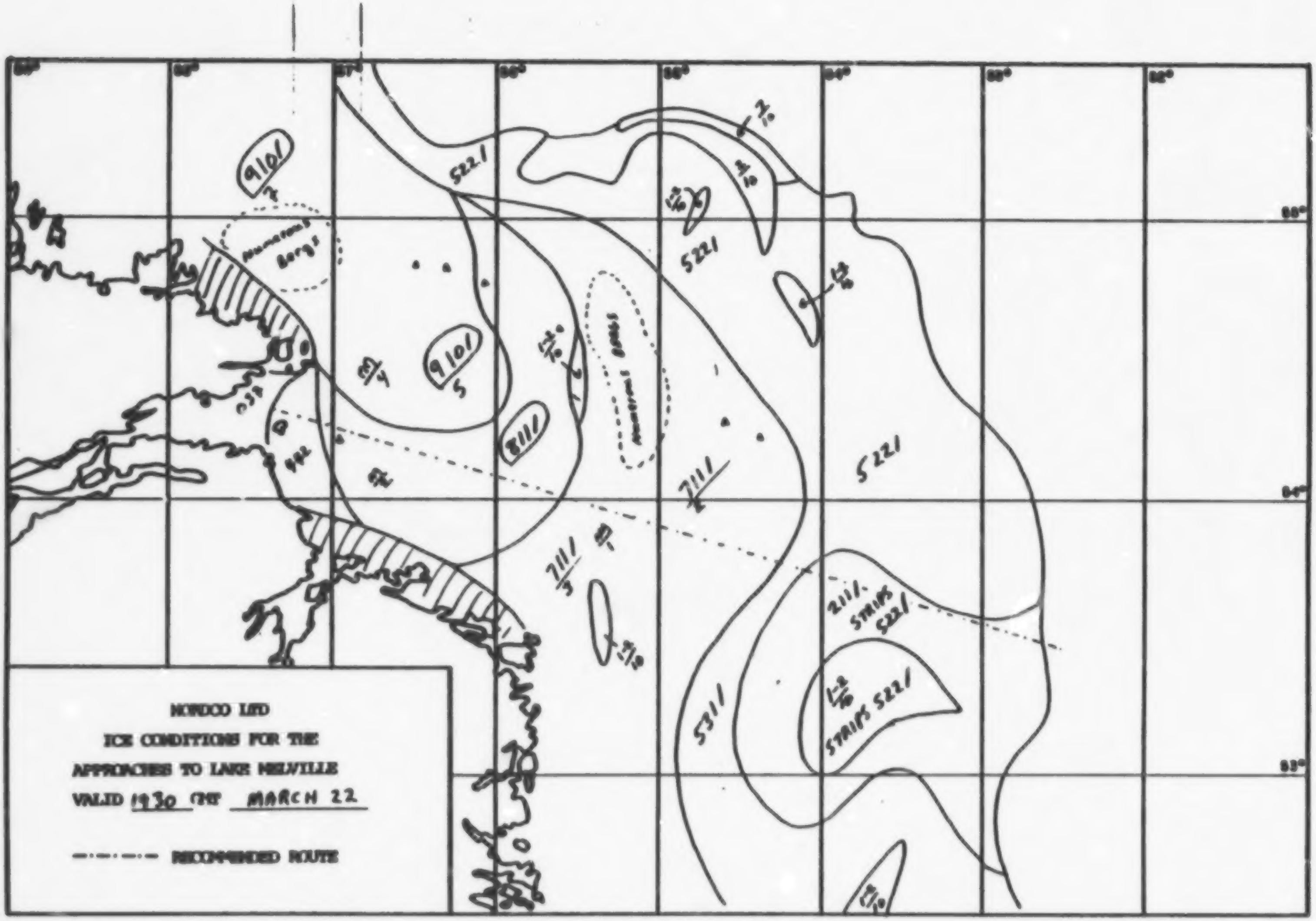
The recommended route extends from 53°27'N, 52°30'W to just north of George Island.

From 53°27'W, 52°30'W to 54°07'W there is 4/10 coverage with 2/10 first year ice, from 54°07'W to 54°17'W there is 9/10 coverage with 5/10 first year ice, from 54°17'W to 55°37'W there is 9/10 coverage with 7/10 first year ice, from 55°37'W to 57°03'W there is 9+/10 coverage with 8/10 first year ice, and from 57°03'W to north of George Is. there is 10/10 coverage of young and new ice.

The area of ice from 55°37'W to 57°03'W is heavily ridged and hummocked.

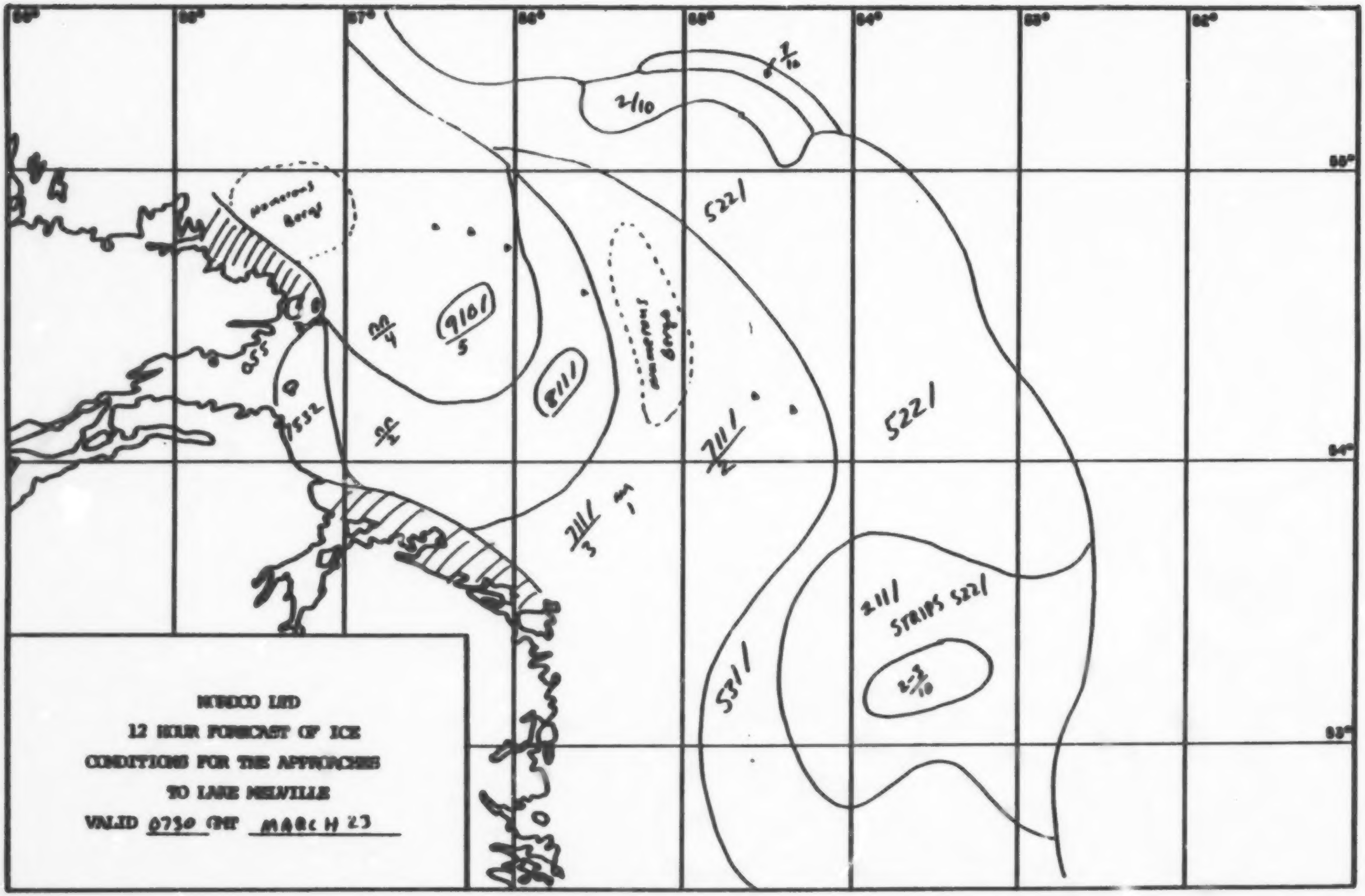
Data Base

This map is bases mainly on data from NOAA satellite imagery for 1706Z March 22. Additional data was from the previous analyses and a SAR flight on March 21st. Data from the flight on the 21st. was received late.

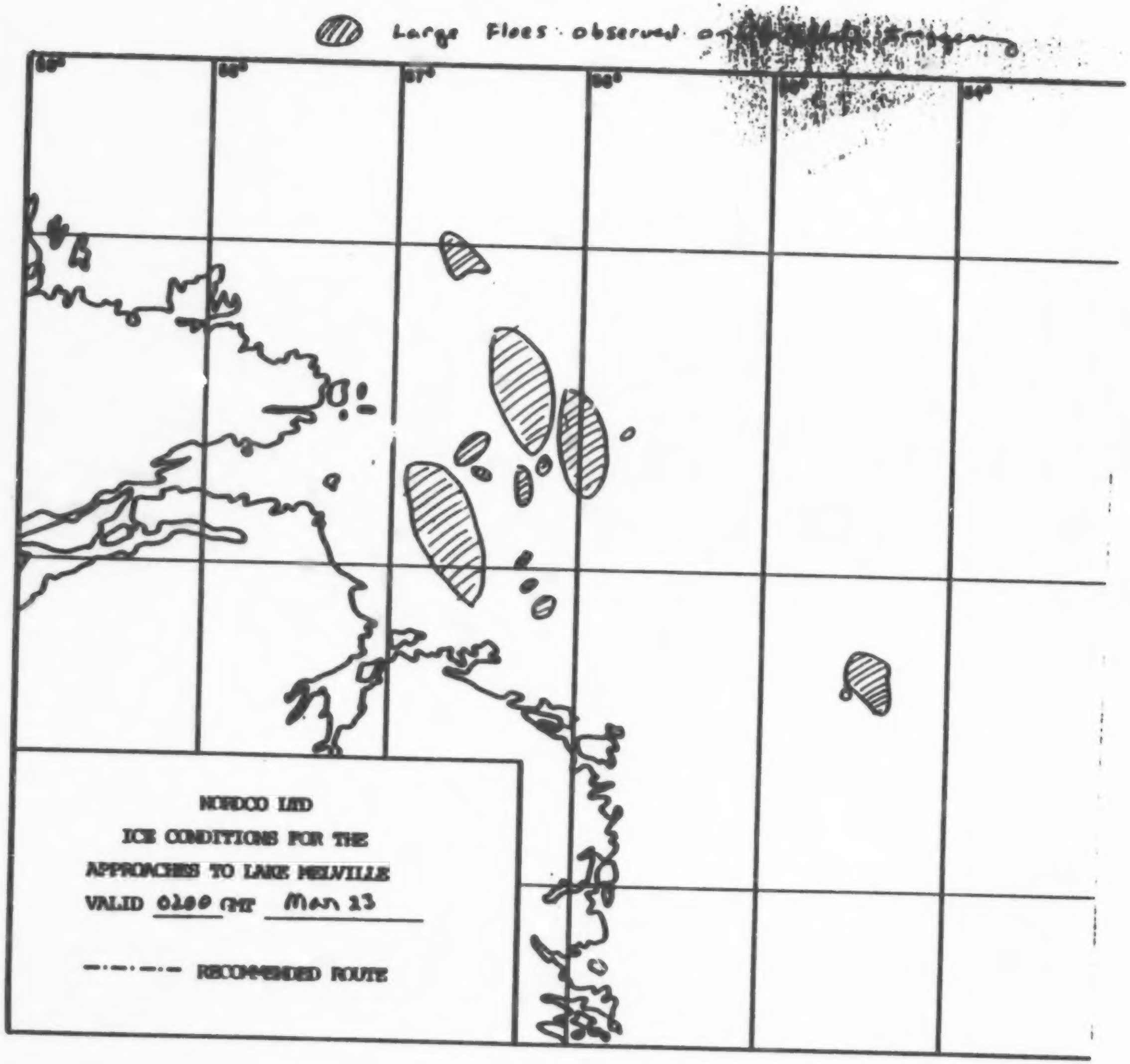

9101
numerous bergs
5221
9101
5
8111
numerous bergs
7111
7111
3
5221
5311
2111
STRIPS 5221
STRIPS 5221
442

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1930 GMT MARCH 22

—·—·— RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
2/10
1/10
5221
Numerous Bergs
Numerous Bergs
9101
5
8111
$\frac{m}{4}$
7111
2
7111
3
5221
5311
2111
STRIPS 5221
2-3/10
0
7532
055

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0730 GMT MARCH 23


▨ Large Floes observed on [illegible] imagery
NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 0200 GMT Mar 23
—·—·—·— RECOMMENDED ROUTE

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1230 GMT, Tuesday, March 23, 1982

Weather Summary

At forecast time the study area was under influence of a ridge of high pressure and winds over the area were light and variable. This ridge will continue to influence the area for the next 24 hours. During this period winds will become light to moderate northwestlys.

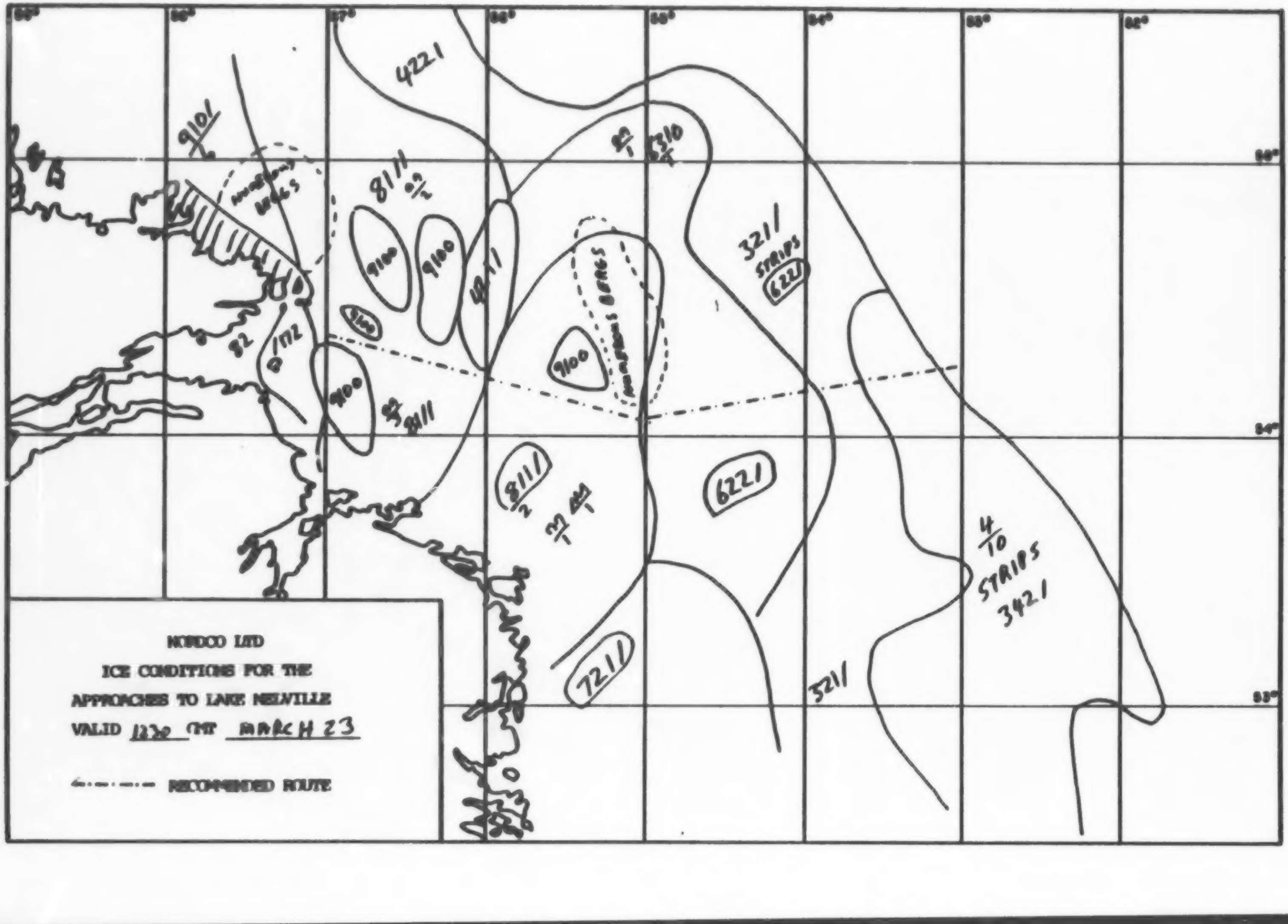
Recommended Route

The recommended route extends from 54°16'N, 53°W to 54°03'N, 55°W then to 54°22"N, 57°W and then along the shipping route into the Lake.

From 54°16'N, 53°W to 53°37'W there will be 4/10 coverage with strips of 9/10 coverage, from 53°37'W to 53°56'W there will be 6/10 coverage with 3/10 first year ice and strips of 9+/10, from 53°56'W to 55°02'W there will be 9+/10 coverage with 6/10 first year ice, from 55°02'W to 56°W there will be 9+/10 coverage with 8/10 first year ice and 1-2/10 ridging and hummocking, and from 56°W to 57°W there will be 9/10 coverage with 8/10 first year ice and 3/10 hummocking.

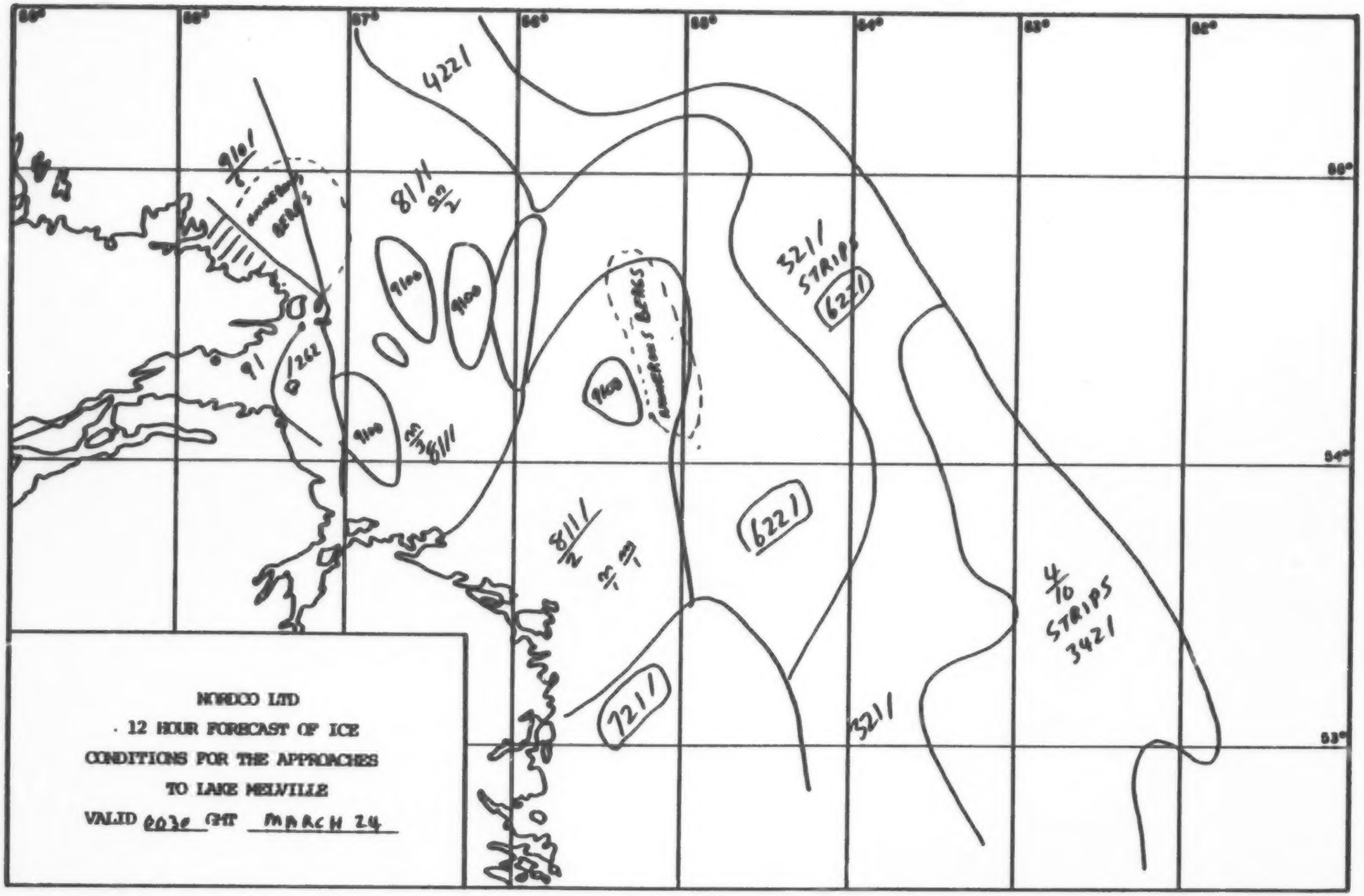
Data Base

Todays map is based on IR N-7 imagery for 0700Z Marcy 23, visual N-7 imagery for 1700Z March 22, AES SLAR data for March 22, ship reports and the previous analyses.


4221
9101
8111
9100
9100
9100
8111
82
3211
STRIPS
6221
6221
8111
7211
3211
4/10
STRIPS
3421

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1230 GMT MARCH 23

←·—·—·— RECOMMENDED ROUTE


59°
58°
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55°
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53°
52°
55°
54°
53°
4221
9101
BERGS
81/1
9/2
9100
9100
9100
9100
91
0/262
81/1
NUMEROUS BERGS
3211
STRIPS
6221
6221
8111
2
7211
3211
4/10
STRIPS
3421

NORDCO LTD
· 12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0030 GMT MARCH 24

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1930 GMT, Tuesday, March 23, 1982

Weather Summary

At forecast time the area was under the influence of a ridge of high pressure and winds were light southwesterly. This ridge will continue to influence the area for the next 24 hours, but winds will become light to moderate northwesterlys.

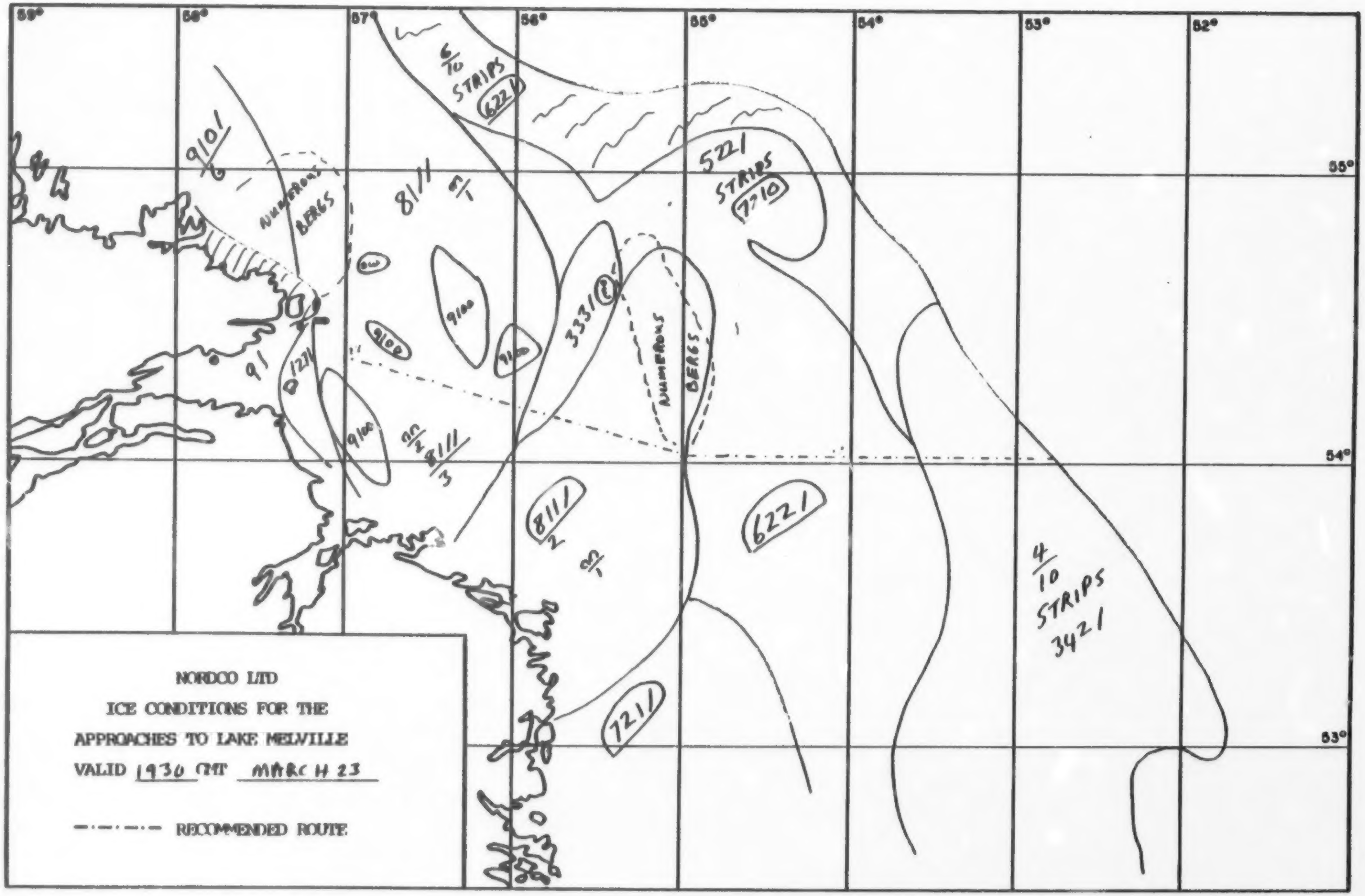
Recommended Route

The recommended route extends from 54°01'N, 52°50'W to 54°02'N, 55°W then to 54°22'N, 56°W.

From 54°02'N, 52°50'W to 53°37'W there is 4/10 coverage in strips with 3/10 first year ice in the strips, from 53°37'W to 55°W there is 9+/10 coverage with 6/10 first year ice, from 55°W to 55°47'W there is 9+/10 coverage with 8/10 first year ice, from 55°47'W to 55°56'W there is 9/10 coverage with 3/10 first year ice and from 55°56'W to 57°W there is 9/10 coverage with 8/10 first year ice of which 2/10 is ridged and hummocked.

Data Base

This map is based on N-7 satellite imagery for 1700Z March 23, ship reports and the previous analysis.



59°
58°
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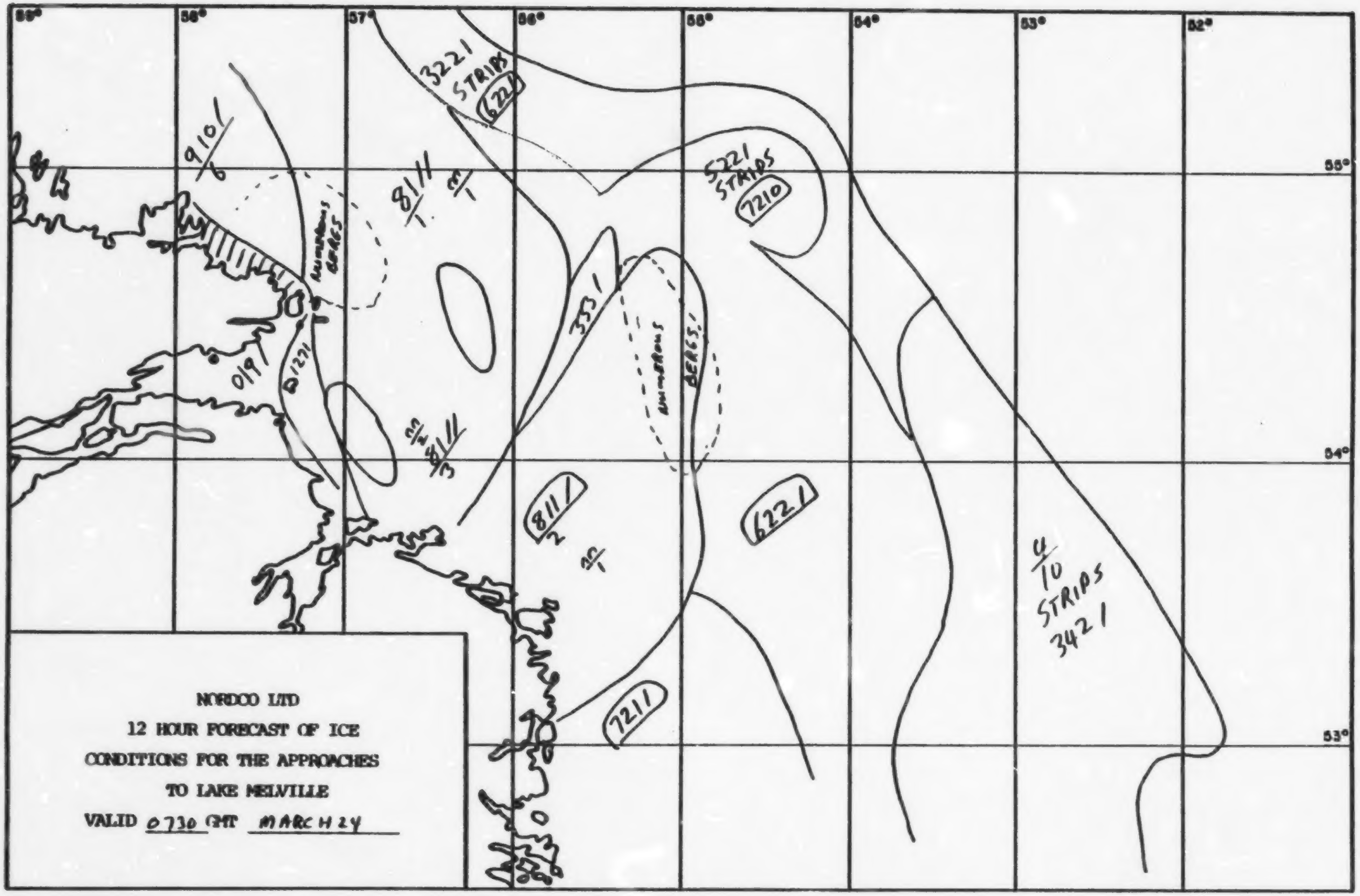
56°
55°
54°
53°
52°
55°
54°
53°
9101/6
NUMEROUS BERGS
81/1
8/1
6/10 STRIPS 6221
5221 STRIPS 7710
9100
9100
3331
NUMEROUS BERGS
91
1271
9100
81/11/3
8111/2
6221
4/10 STRIPS 3421
7211

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1930 GMT MARCH 23

—·—·— RECOMMENDED ROUTE


59°
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53°
3221
STRIPS
6221
9101
6
NUMEROUS
BERGS
811
1
3
1
0191
1271
811
3
3/2
5221
STRIPS
7210
3331
NUMEROUS
BERGS
811
2
3/1
6221
7211
4/10
STRIPS
3421

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0730 GMT MARCH 24

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1230 GMT, Wednesday, March 24

Weather Summary

At forecast time a ridge of high pressure continued to influence the area. Winds over the pack were light and variable. No change is expected during the next 24 hours.

Recommended Route

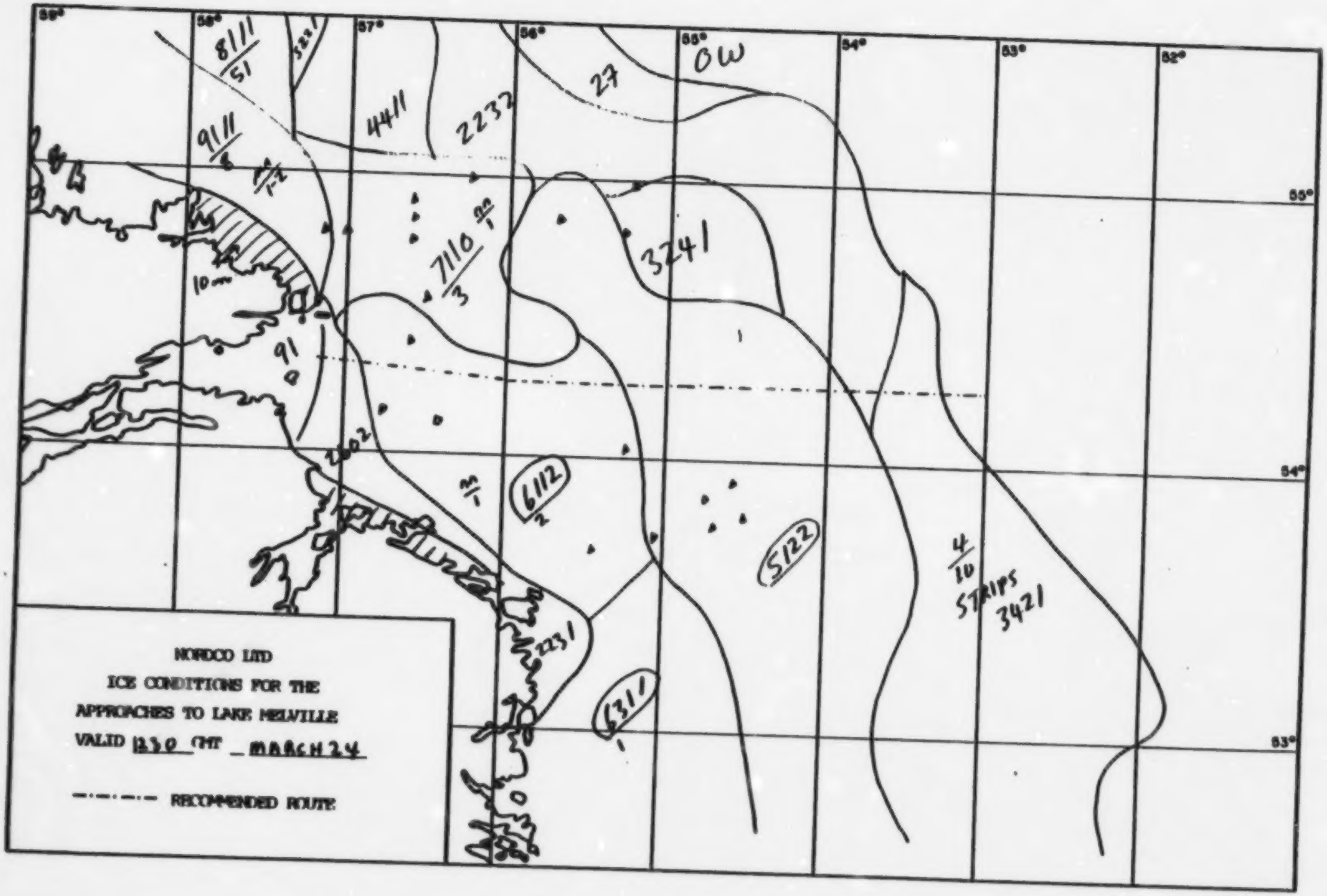
The recommended route extends from 54°16'N 53°W to 54°16'N, 56°00'W then to just north of George Is.

From the edge of the pack near 54°16'N, 53°20'W to 53°40'W there will be 4/10 coverage with strips of 9/10 coverage, from 53°40'W to 53°50'W there will be 9/10 coverage with 2/10 first year ice, from 53°50'W to 55°20'W there will be 9+/10 coverage with 5/10 first year ice, from 55°20'W to 56°55'W there will be 9+/10 coverage with 6/10 first year ice of which 1/10 will be hummocked and from 56°55'W to 57°07'W there will be 10/10 coverage with 2/10 first year ice.

Data Base

SLAr

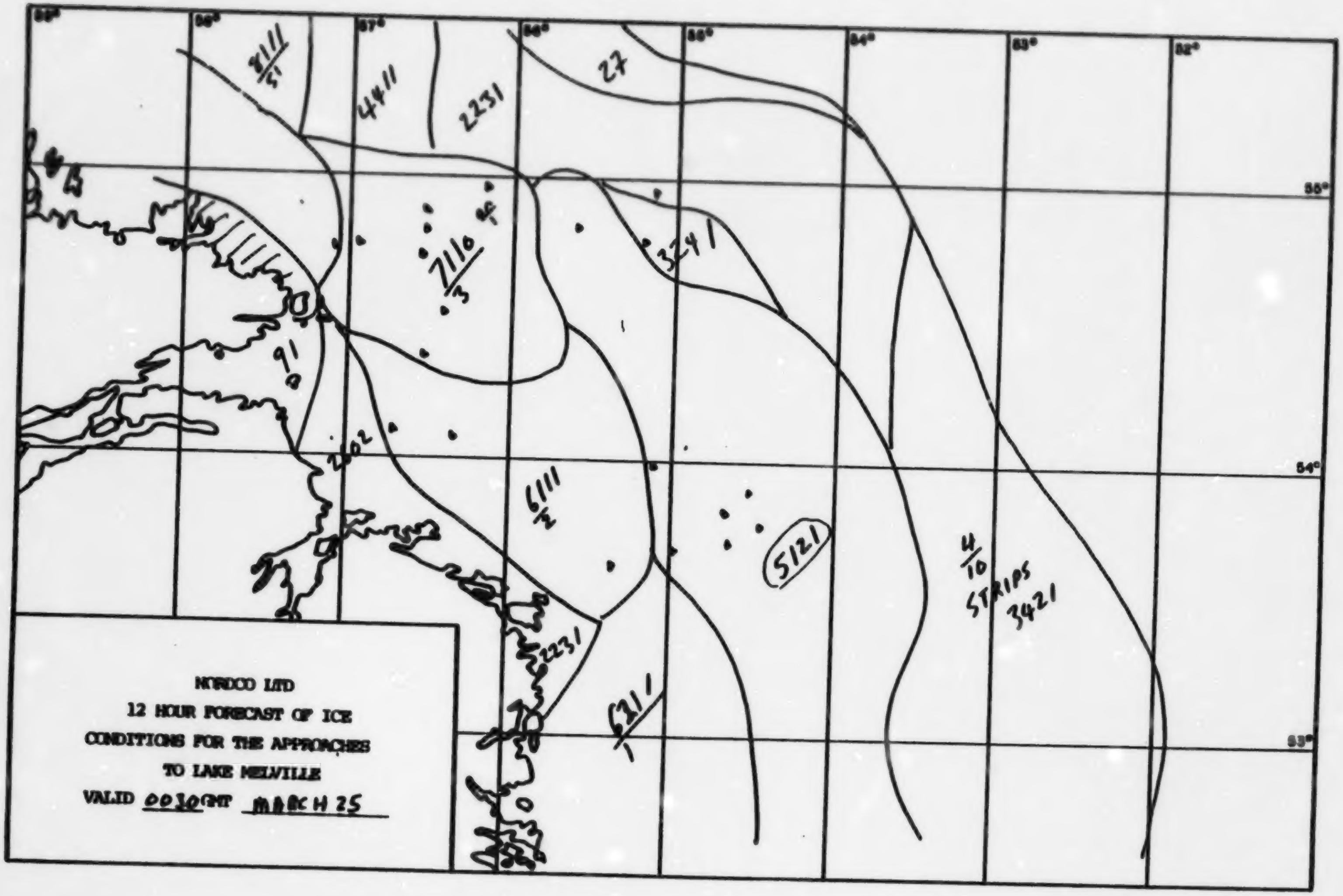
This analyses is based on data from an AES SLAR flight on March 23, visual and SAR data from Goose Bay for March 23, N-7 visual imagery for March 23, N-7 IR imagery for March 24, the latest ship reports and the previous analyses.



59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
8111/51
3221
9111/8
1/1-2
4411
2232
27
OW
7110/3
m/1
3241
10m
91
2202
m/1
6112/2
5122
4/10 STRIPS 3421
2231
1311/1

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1230 GMT MARCH 24

-·-·-·- RECOMMENDED ROUTE


59°
58°
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56°
55°
54°
53°
52°
55°
54°
53°
8111/51
4411
2231
27
7110/3
3241
91
2202
6111/2
5121
4/10 STRIPS 3421
2231
6311/1

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0030GMT MARCH 25

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1930 GMT, Wednesday, March 24

Weather Summary

At forecast time the area continued to be influenced by a ridge of high pressure. Winds are presently light and variable. During the next 24 hours the winds will become light westerly.

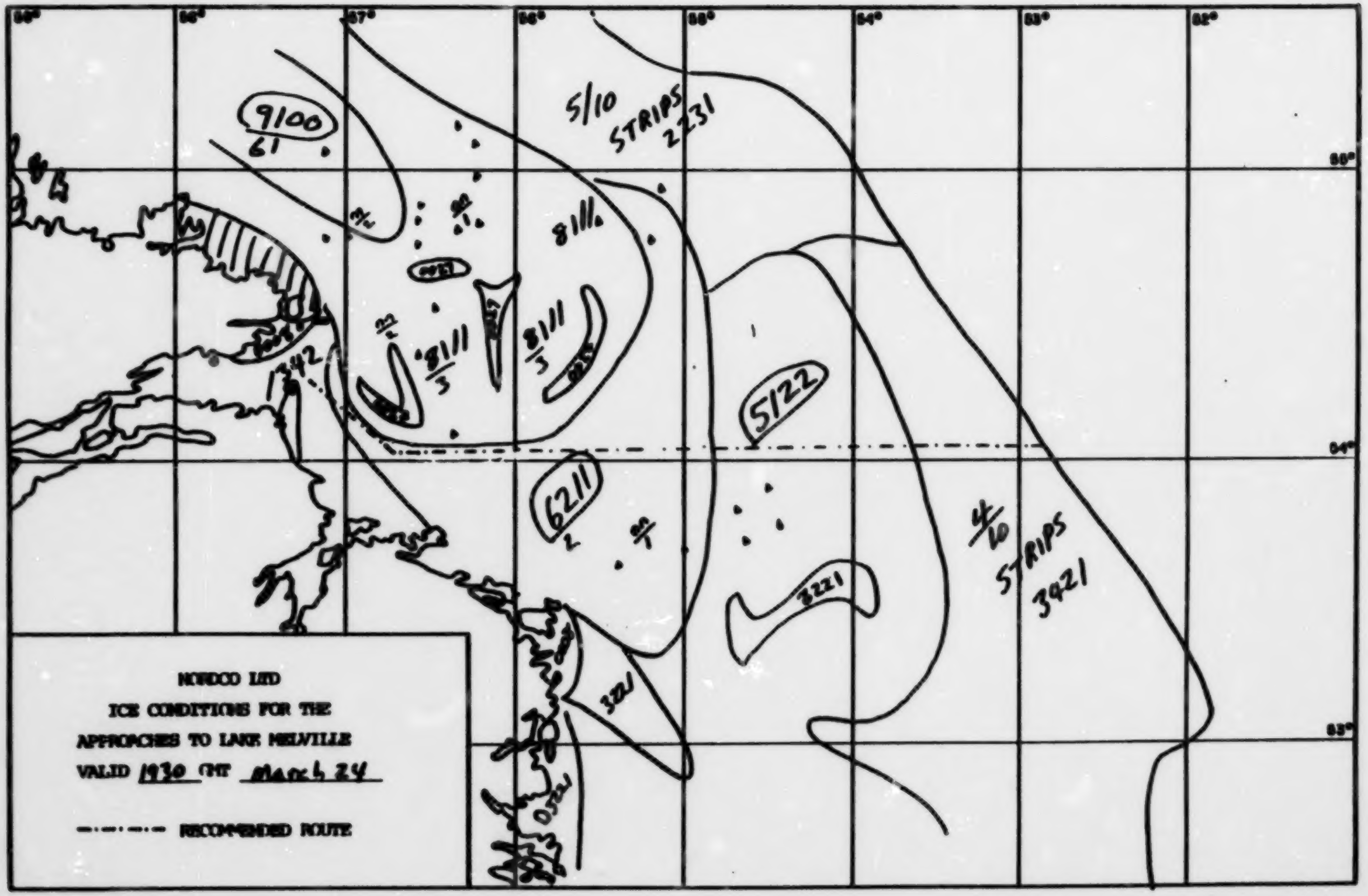
Recommended Route

The recommended route extends from 54°02'N, 52°50'W to 54°02'N, 56°45'W then to just north of George Island.

From 54°02'N, 52°50'W to 53°37'W there will be 4/10 coverage in strips, from 53°37'W to 54°50'W there will be 9+/10 coverage with 5/0 first year ice, from 54°50'W to 57°05' there will be 9+/10 coverage with 6/10 first year ice of which 1/10 will be hummocked.

Data Base

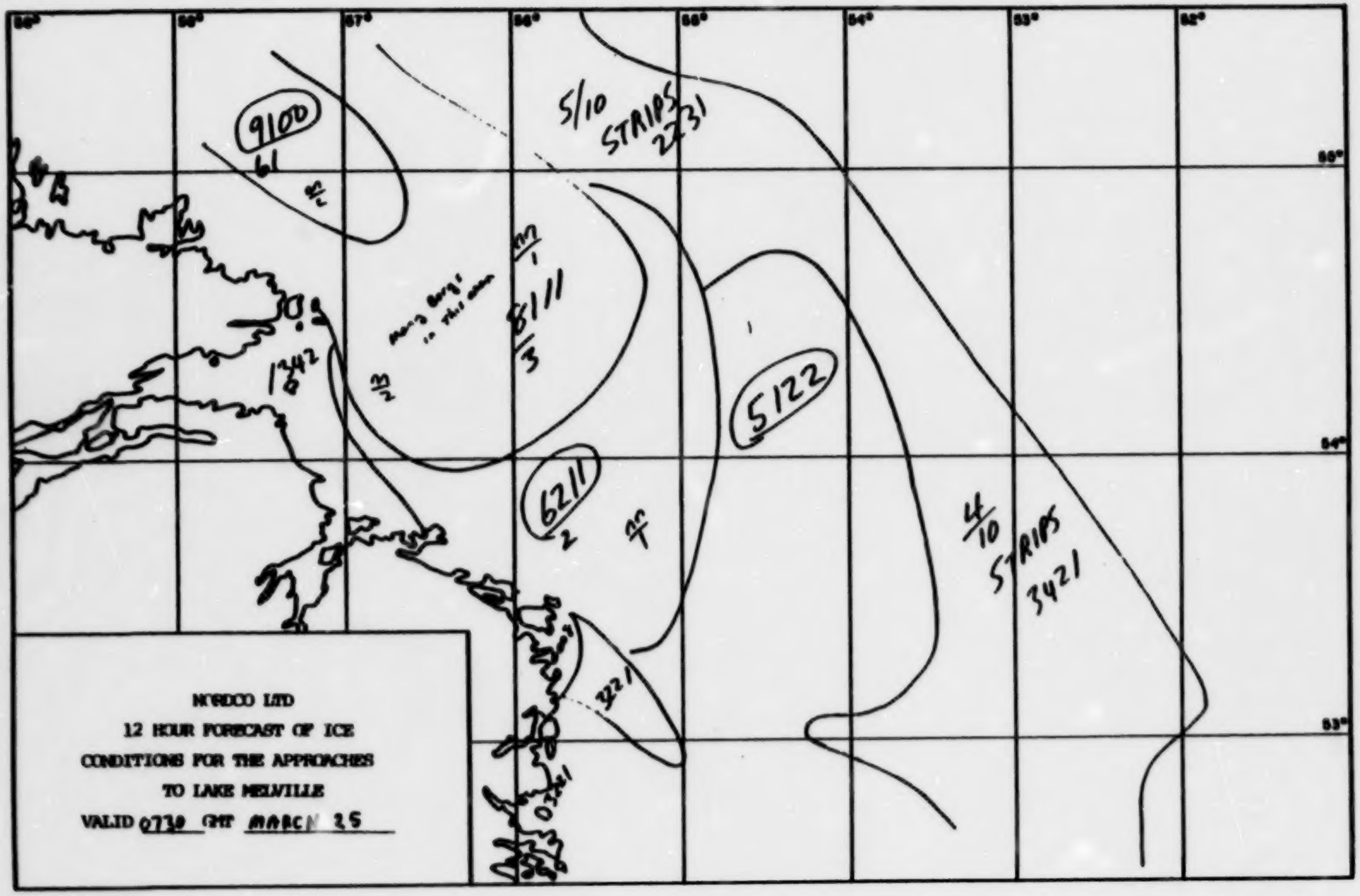
This analyses is based on visual and SAR flight data from Goose Bay, N-7 visual imagery for March 24, ship reports and the previous analyses.



5/10
STRIPS
2231
9100
61
81/11
8111
3
5122
6211
2
4/10
STRIPS
3421
3221
3221
0321
1342

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1930 GMT March 24

-·-·-·- RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
9100
61
5/10
STRIPS
2231
Many Bergs in this area
8/111
3
6211
2
5122
4/10
STRIPS
3421
1342
1
321
0321

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0730 GMT MARCH 25

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1230 GMT, Thursday, March 25, 1982

Weather Summary

At forecast time the area continued to be influenced by a ridge of high pressure but a low northwest of the area will move north of the area tommorow and winds are forecast to become moderate to strong southwesterly during the next 24 hours.

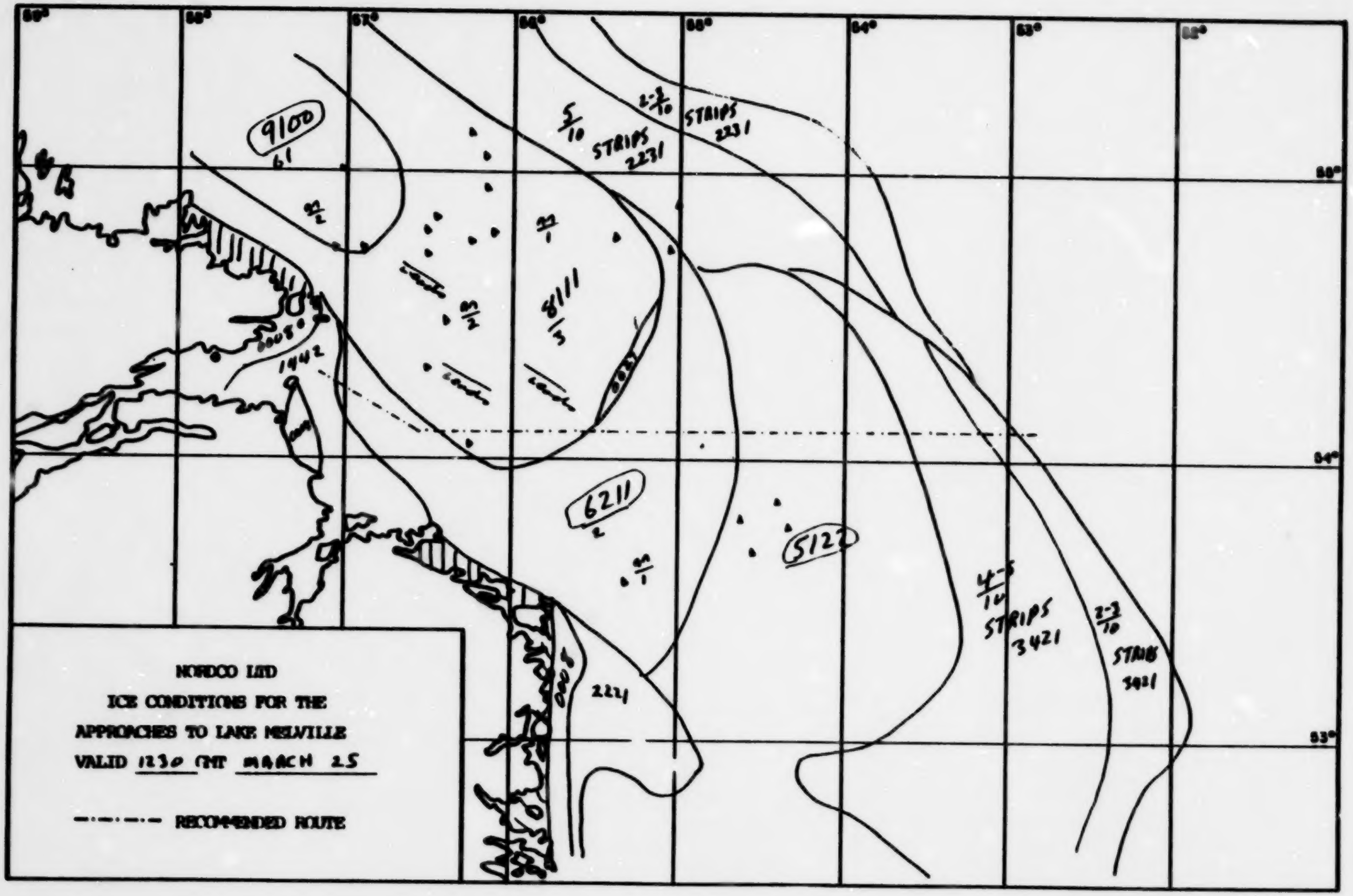
Recommended Route

The recommended route extends from 54°05'N, 52°57'W to 54°05'N, 56°34'W then to just north of Georges Is.

From 54°05'N, 52°57'W to 53°10'W there will be 2/10 to 3/10 coverage in strips, from 53°10'W to 53°38'W there will be 4/10 to 5/10 coverage in strips, from 53°38'W to 54°40' there will be 9+/10 coverage with 5/10 first year ice, from 54°40'W to 55°33'W there will be 9+/10 coverage with 6/10 first year ice, from 55°33'W to 56°28'W there will be 9/10 coverage with 8/10 first year ice with 1/10 of this ice hummocked and a number of NW to SE leads, from 56°28'W to 57°02'W there will be 9+/10 coverage with 6/10 first year ice.

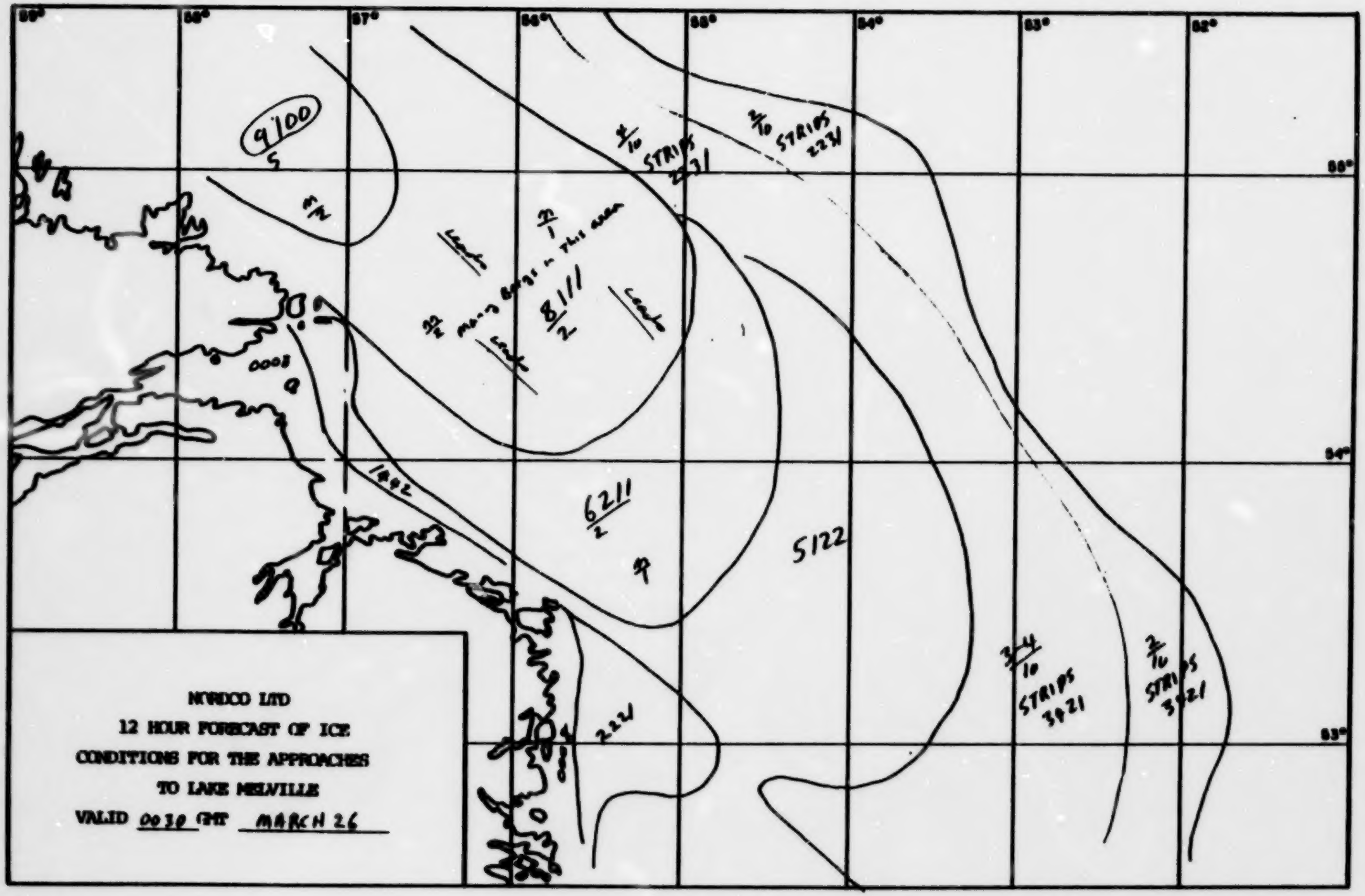
Data Base

This analyses is based on Data from the previous map, GOES imagery for March 25 and ship reports.


69°
68°
67°
66°
65°
64°
63°
62°
55°
54°
53°
9100
61
5/10 STRIPS 2231
2-3/10 STRIPS 2231
8111
5
6211
2
5122
4-5/10 STRIPS 3421
2-3/10 STRIPS 3421
2224
1442

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1230 GMT MARCH 25

-·-·-·- RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
9|100
5
Leads
Leads
Leads
Many Bergs in this area
8/1/1/2
6211/2
5122
1442
2221
0008
STRIPS 2231
STRIPS 2231
3-4/10 STRIPS 3421
2/10 STRIPS 3421

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0030 GMT MARCH 26

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1930 GMT, Thursday, March 25, 1982

Weather Summary

The forecast area continues to be under the influence of a high pressure system. Winds are presently moderate south westerlies and the area will continue to be influenced by these winds for the next 24 hours.

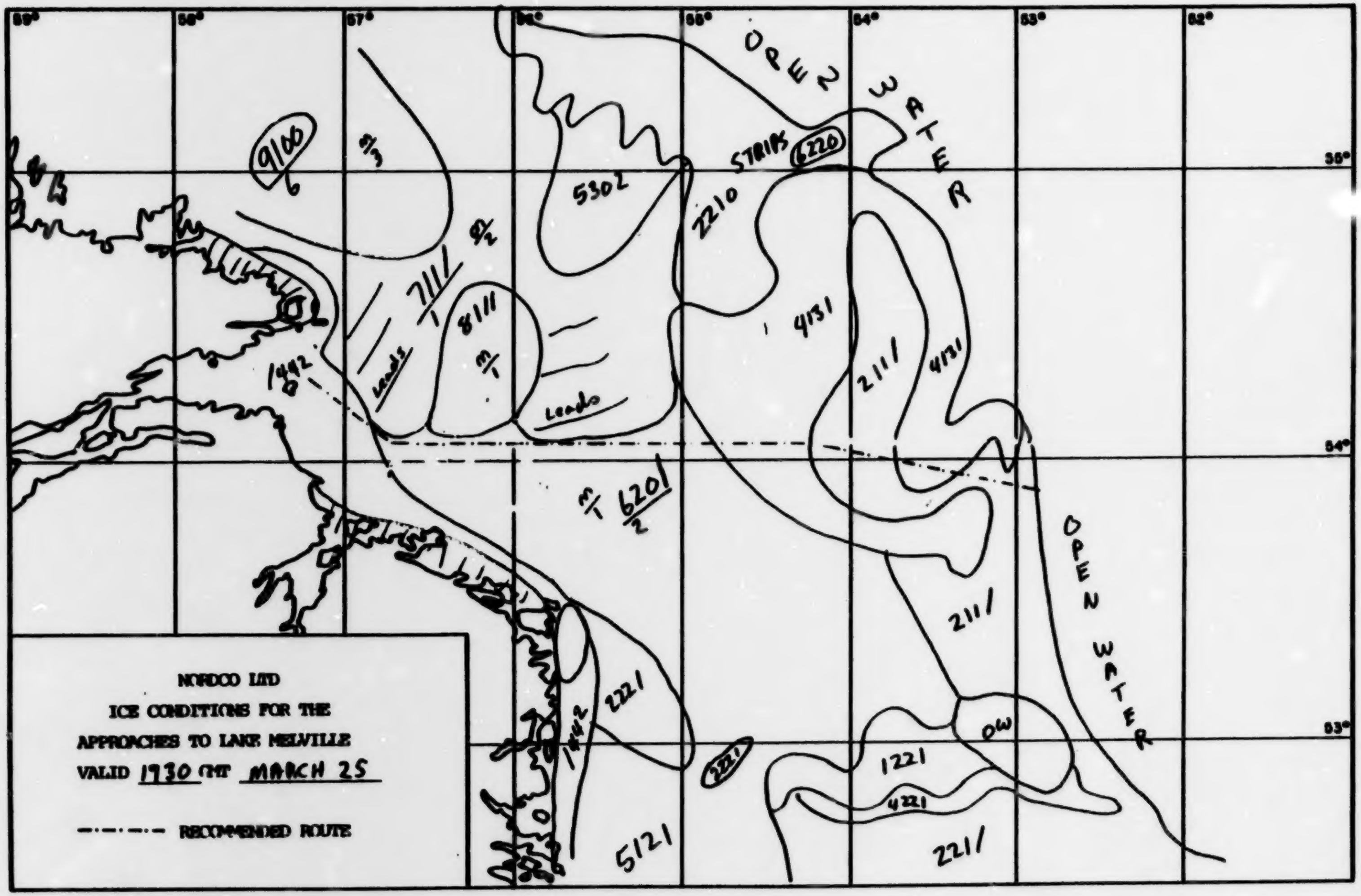
Recommended Route

The recommended route extends from 53°53'N, 52°52'W to 54°04'N, 54°20'W then due west to 54°04'N, 56°45'W then to just north of Georges Is.

From 53°53'N, 52°52'W to 53°25'W there is 4/10 coverage with 2/10 first year ice, from 53°25'W to 53°45'W there is 9/10 coverage with 4/10 first year ice, from 53°45'W to 54°18'W there is 4/10 coverage with 2/10 first year ice, from 54°18'W to 54°49'W there is 9/10 coverage with 4/10 first year ice, from 54°49'W to 56°50'W there is 9/10 coverage with 6/10 first year ice and from 56°50'W to north of George Is there is 10/10 coverage of young and new ice.

Data Base

This analysis is based on NG imagery for 1811Z March 25, ship reports and the previous analysis.


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
OPEN WATER
OPEN WATER
STRIPS 6220
9100
6
3/3
8/2
7111
1
8111
3/1
Leads
Leads
5302
2210
4131
2111
4131
1442
Ω
3/1 6201
2
2111
OW
1221
4221
2211
2221
1442
5121
2221

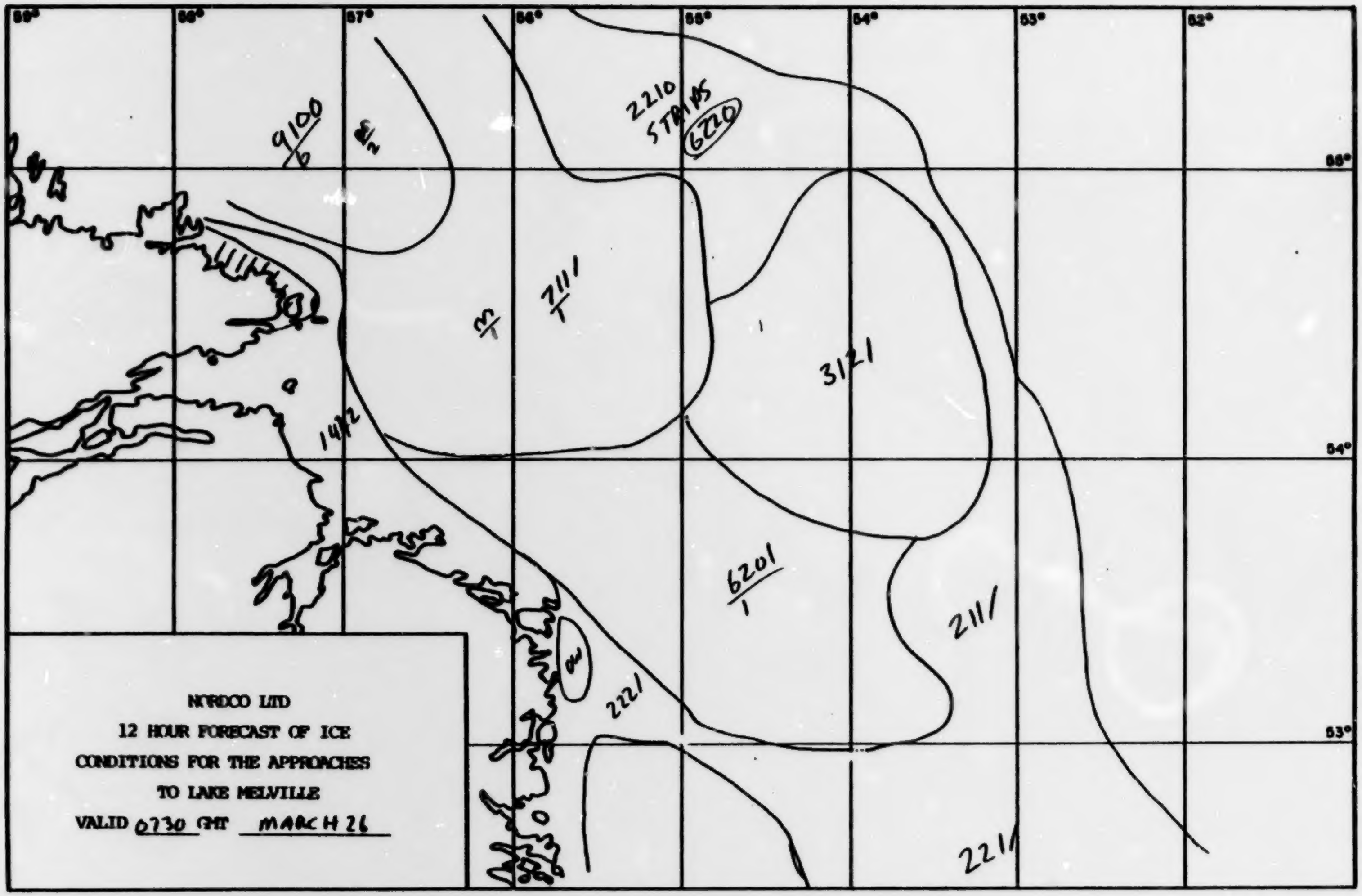
NORDCO LTD

ICE CONDITIONS FOR THE

APPROACHES TO LAKE MELVILLE

VALID 1930 GMT MARCH 25

—·—·— RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
9100/6
3/1
2210
STRIPS
6220
7111/1
3/1
3121
1
1492
6201/1
2111
2221
2211

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0730 GMT MARCH 26

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1230 GMT, Friday, March 26, 1982

Weather Summary

The forecast area continues to be under the influence of a ridge of high pressure. Winds are presently light to moderate southwesterly and are forecast to change to strong to gale force north easterlies by Saturday morning.

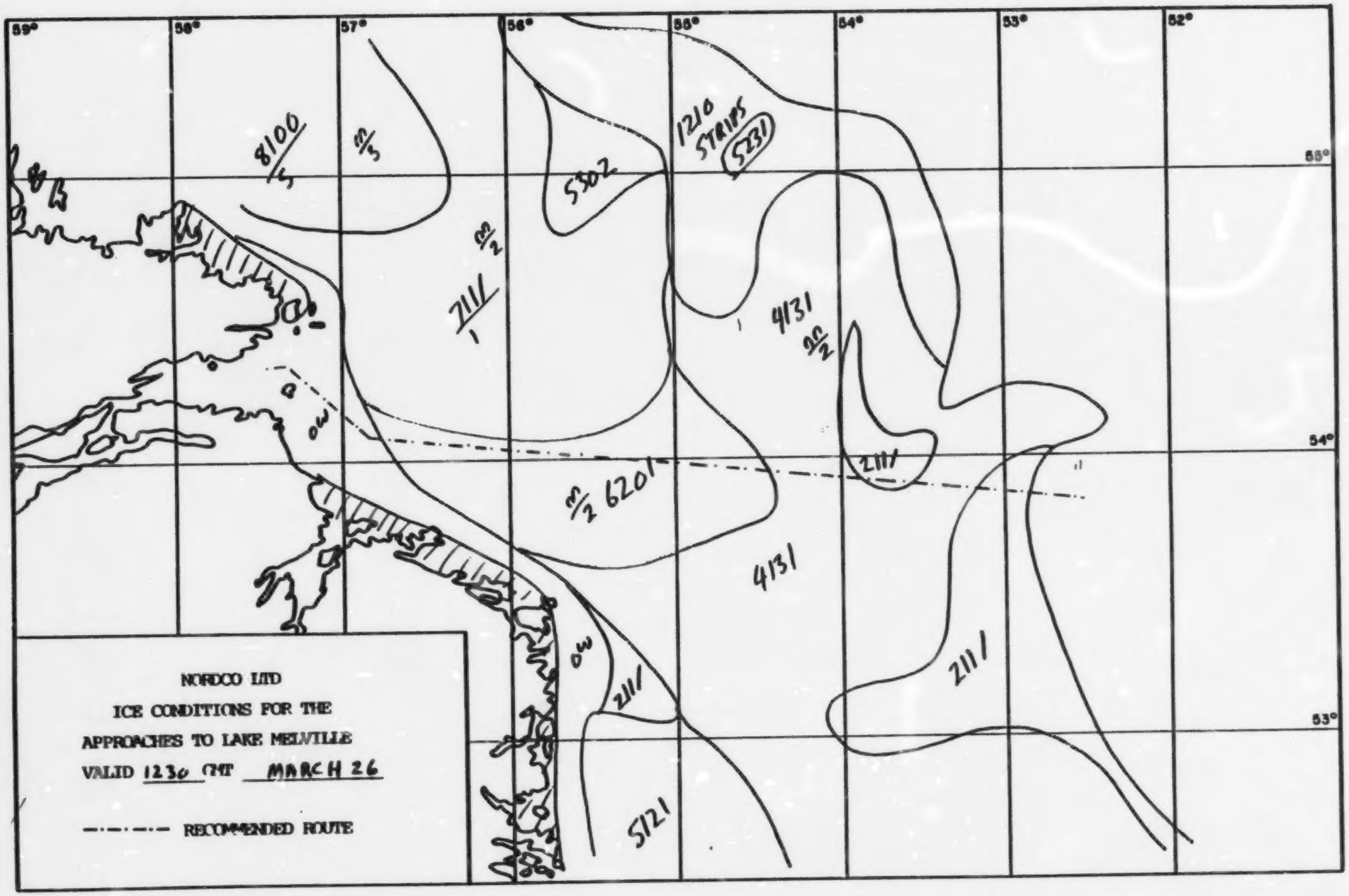
Recommended Route

The recommended route extends from 53°52'N, 52°50'W to 54°05'N to 56°52'W then to just north of Georges Is.

From 53°52'N, 52°50'W to 53°12'W there is 4/10 coverage with 2/10 first year, from 53°12'W to 54°30'W there is 9/10 coverage with 4/10 first year ice, from 54°30'W to 56°49'W there will be 9/10 coverage with 6/10 first year ice of which 2/10 is hummocked.

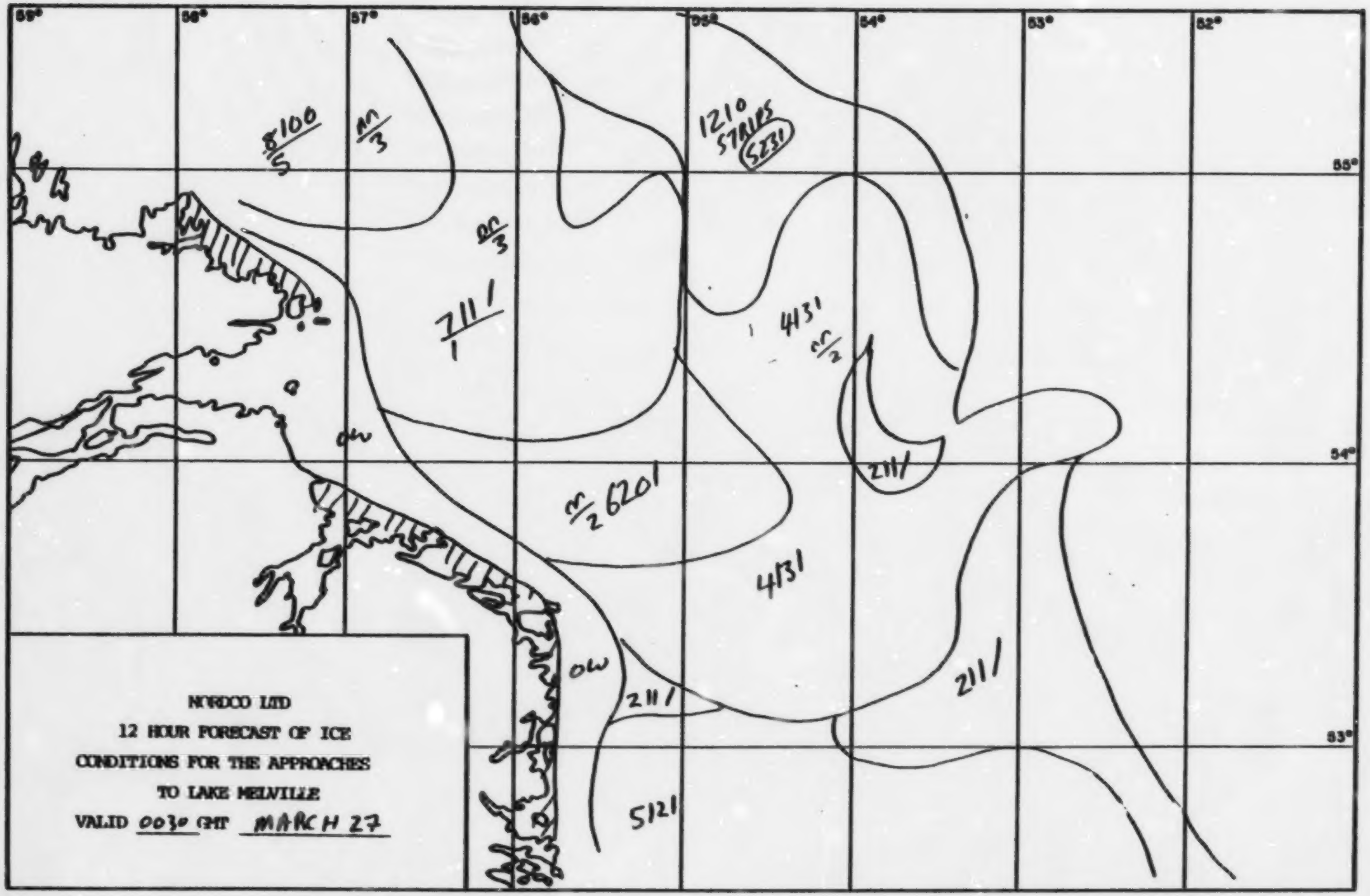
Data Base

This analyses is based on GOES imagery for 1132Z March 26, N-7 IR imagery for 0700Z March 26, ship reports for 12Z, the previous analysis and AES SLAR Data for March 24.


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
8100
2111
5302
1210
STRIPS
5231
4131
6201
4131
2111
2111
OW
OW
2111
5121

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1230 GMT MARCH 26

-·-·-·- RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
8100
5
nr
3
1210
STRIPS
5231
nr
3
7111
1
4131
nr
2
ow
nr
2
6201
211/
4131
ow
211/
211/
5121

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0030 GMT MARCH 27

Ice and Weather Summary Issued for the Approaches to Lake Melville at 1930 GMT, Friday, March 26, 1982

Weather Summary

Winds over the area continue to be light to moderate south westerlies. By early Saturday morning the winds will become strong easterlies.

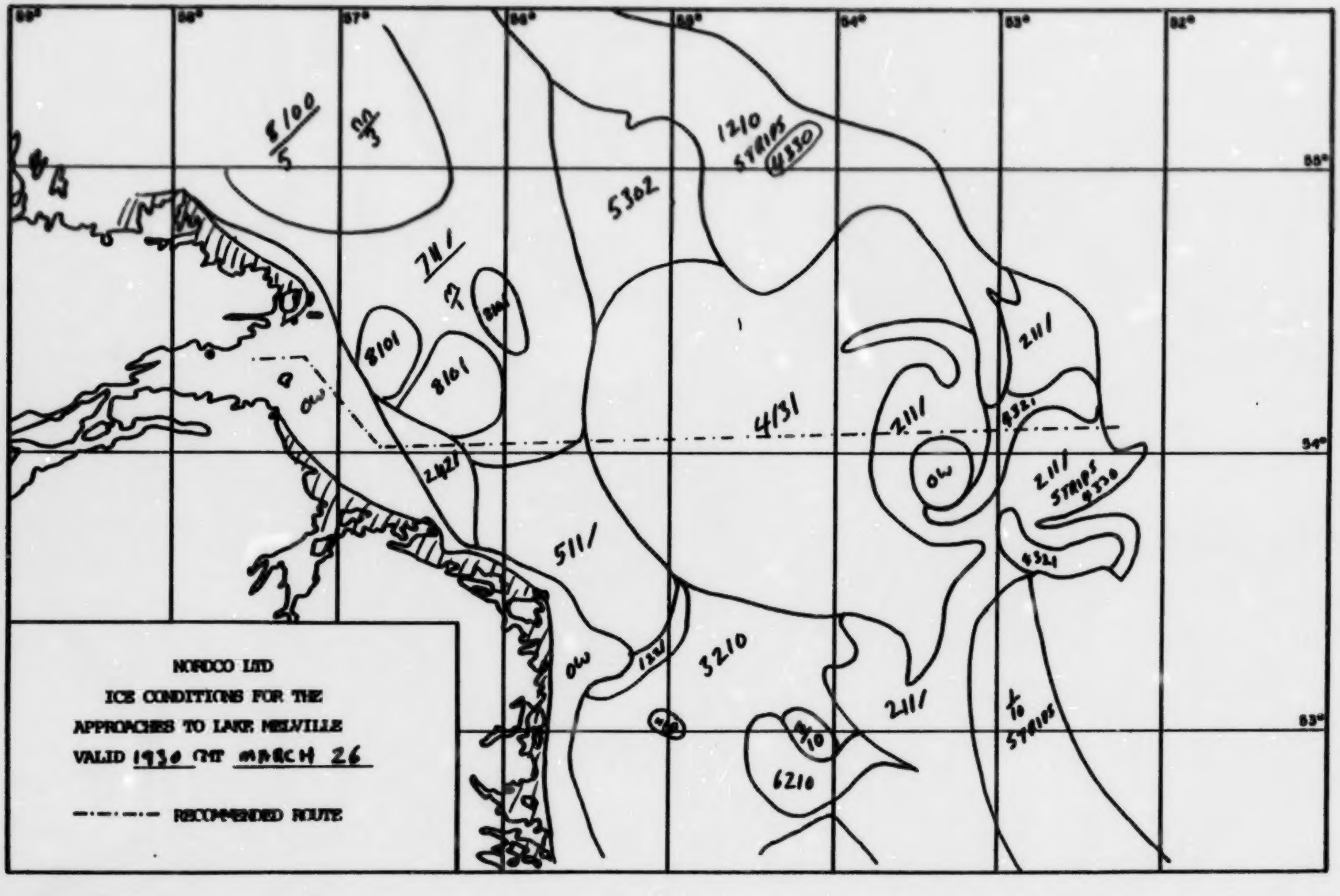
Recommended Route

The recommended route extends from 54°06'N, 52°20'W to 54°01'N, 56°45'W then northwest to just north of Georges Is.

From 54°06'N, 52°20'W to 53°45'W there is a 4/10 coverage with 2/10 first year ice and areas of 9/10 coverage, from 53°45'W to 55°30'W there is 9/10 coverage with 4/10 first year ice, from 55°30'W to 56°21'W there is 9/10 coverage with 7/10 first year ice and from 56°21'W to 56°45'W there is 8/10 coverage with 2/10 first year ice and west of 56°45'W there is open water.

Data Base

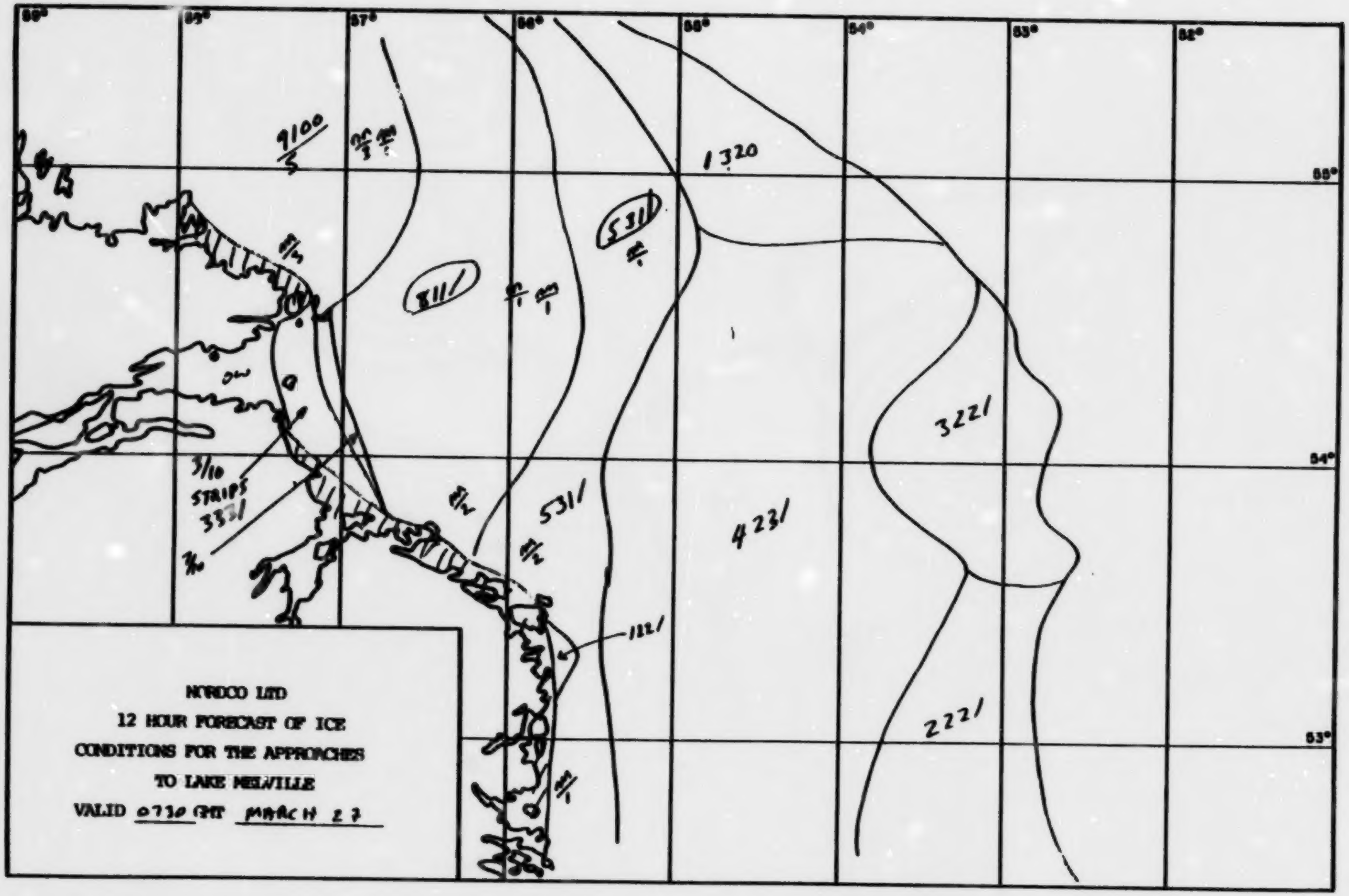
This analyses is based on N-7 imagery for 1756Z March 26 and the previous analyses.



59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
8100/5
7/3
7H1/7/3
8101
8101
8101
OW
2421
5302
1210 STRIPS 4330
4131
5111
OW
1231
3210
6210
2111
2111
4321
OW
2111 STRIPS 4320
4321
2111
1/10 STRIPS

NORDCO LTD
ICE CONDITIONS FOR THE
APPROACHES TO LAKE MELVILLE
VALID 1930 GMT MARCH 26

—·—·— RECOMMENDED ROUTE


59°
58°
57°
56°
55°
54°
53°
52°
55°
54°
53°
9100/3
1320
5311
8111
OW
3/10
STRIPS
3331
5311
4231
3221
2221
1221

NORDCO LTD
12 HOUR FORECAST OF ICE
CONDITIONS FOR THE APPROACHES
TO LAKE MELVILLE
VALID 0730 GMT MARCH 27

KEY TO ICE SYMBOLS

CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or greater}}$$

$$\frac{\text{Cmy Csy Cfy Cgy Cgw Cg Cn}}{\text{Nmy Nsy Nfy Ngw Ng Nn}}$$

Example $\frac{20.3410}{1\quad 23}$

2-2/10's Multi Year of which
1 1/10 is Medium Floe or Greater
0- No Second Year
. - Decimal Point
3 - 3/10's First Year of which
2 2/10's is Medium Floe or greater
4 - 4/10's Grey White of which
3 3/10's is Medium Floe or greater
1 - 1/10 Grey, no Medium Floe or greater
0 - No New

SNOW COVER

Sn/(n)

(n) tenths on ice

TOPOGRAPHY

$\frac{A\ A}{(n)}$ Rafted ice

$\frac{AAA}{(n)}$

SURFACE FEATURES

Sn/Re Rd Hy Pd Th+ F

$\frac{\cap\cap}{(n)}$ Hummocks

(n) number of tenths

STAGE OF MELTING

$$\frac{Pd}{(n)\ (n)\ Th+(n)\ F}$$

(n)= tenths on ice
(n) th = tenths thaw holes
(n)F = tenths frozen

e.g. 6/120
6- 6/10 Snow Cover
/ -Slant
1 - 1/10 Rafting
2 - 2/10 Ridging
0 - No Hummocks
1 - 1/10 Puddling

THICKNESS OF ICE AND SNOW

T/n · S/n (n) - nearest inch

ICE OF LAND ORIGIN

△ - (n) Icebergs
⏢ - (n) Bergy Bits and growlers
Optional : (n) number in area

WATER FEATURES

+++++ Creek

═ Lead

Polynye

UNDER CAST

Limits

BOUNDARY

——— Observed visually

-‖-‖- Observed by radar

- - - - - - Assumed

○ ○ ○ Limit of Observed date

○○○ Limit of radar date

APPENDIX C

Satellite Imagery

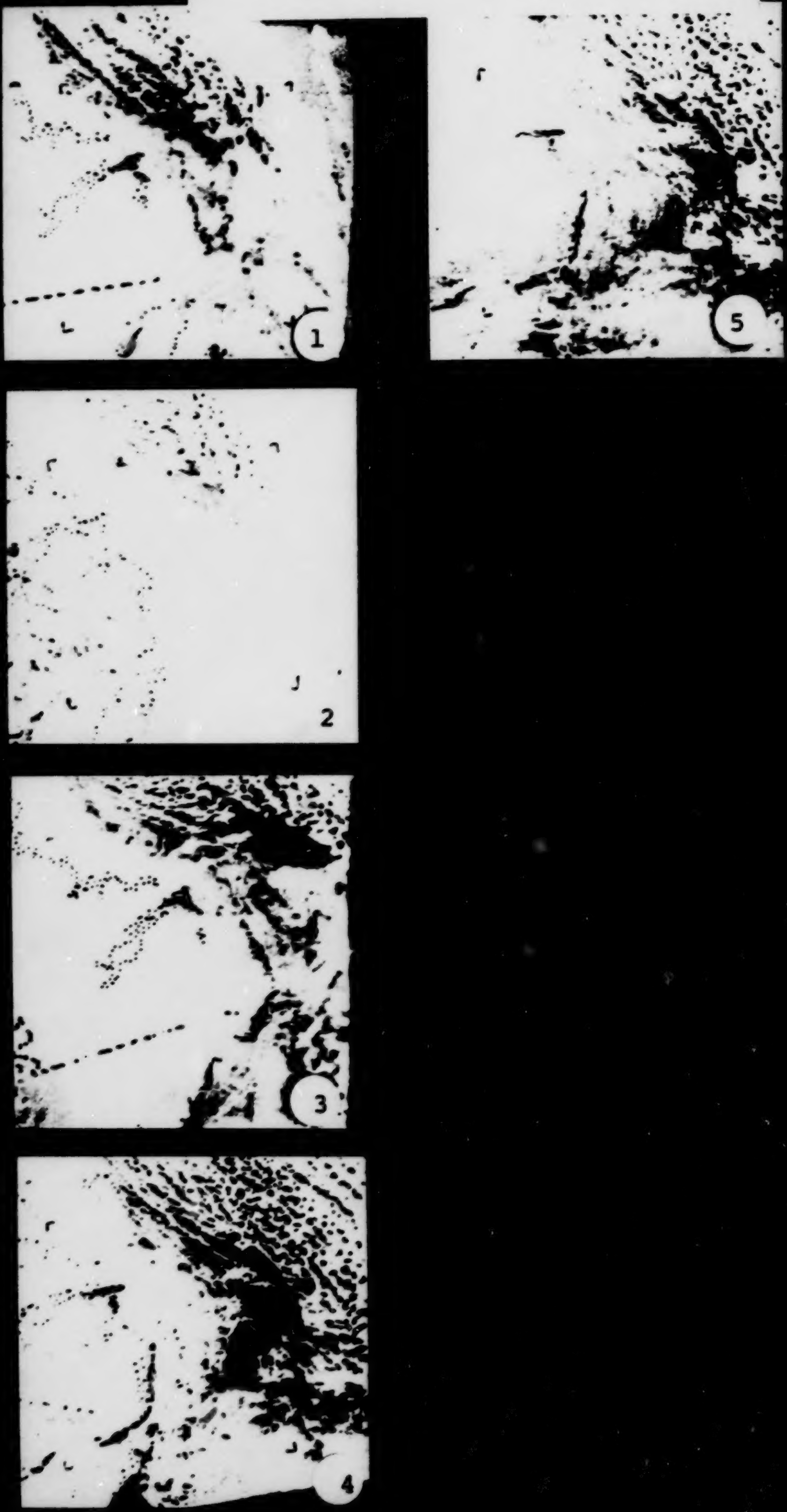
Note: These images have lost some detail in copying.

LIST OF SATELLITE IMAGES

March 20	No. 1	0735Z	NOAA-7	11 µ
	No. 2	1244Z	NOAA-6	VIS
	No. 3	1244Z	NOAA-6	11 µ
	No. 4	1730Z	NOAA-7	VIS
	No. 5	1730Z	NOAA-7	11 µ
March 21	No. 1	0723Z	NOAA-7	4 µ
	No. 2	0723Z	NOAA-7	11 µ
	No. 3	1716Z	NOAA-7	VIS enlargement
	No. 4	1718Z	NOAA-7	VIS
	No. 5	1718Z	NOAA-7	11 µ
March 22	No. 1	0711Z	NOAA-7	11 µ
	No. 2	0711Z	NOAA-7	4 µ
	No. 3	1530Z	GOES	VIS
	No. 4	1706Z	NOAA-7	11 µ
	No. 5	1704Z	NOAA-7	VIS enlargement
	No. 6	1706Z	NOAA-7	VIS
March 23	No. 1	0700Z	NOAA-7	4 µ
	No. 2	0700Z	NOAA-7	11 µ
	No. 3	1632Z	GOES	VIS
	No. 4	1653Z	NOAA-7	VIS enlargement
	No. 5	1653Z	NOAA-7	11 µ
	No. 6	1653Z	NOAA-7	VIS
March 24	No. 1	0648Z	NOAA-7	11 µ
	No. 2	0648Z	NOAA-7	4 µ
	No. 3	1640Z	NOAA-7	NIR enlargement
	No. 4	1822Z	NOAA-7	11 µ
	No. 5	1822Z	NOAA-7	VIS
March 25	No. 1	1811Z	NOAA-7	11 µ
	No. 2	1811Z	NOAA-7	VIS
March 26	No. 1	0625Z	NOAA-7	11 µ
	No. 2	0625Z	NOAA-7	4 µ
	No. 3	0804Z	NOAA-7	11 µ
	No. 4	1132Z	GOES	VIS
	No. 5	1531Z	GOES	VIS
	No. 6	1632Z	GOES	VIS
	No. 7	1756Z	NOAA-7	VIS enlargement
	No. 8	1759Z	NOAA-7	11 µ
	No. 9	1759Z	NOAA-7	VIS

Satellite Imagery

March 20



Satellite Imagery
March 21

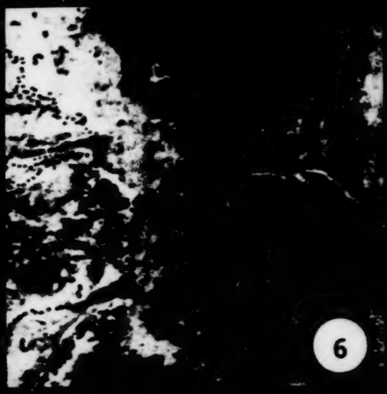
Satellite Imagery

March 22

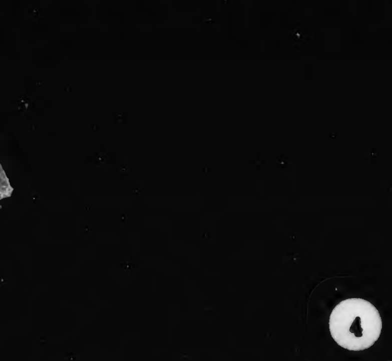
1

5

2


6

3


4

Satellite Imagery
March 23

1

4

2

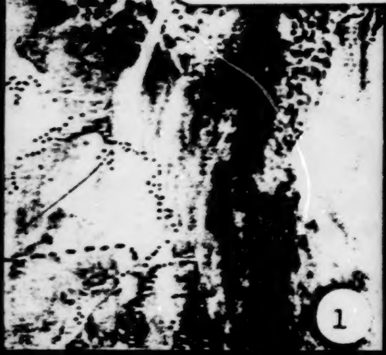
5

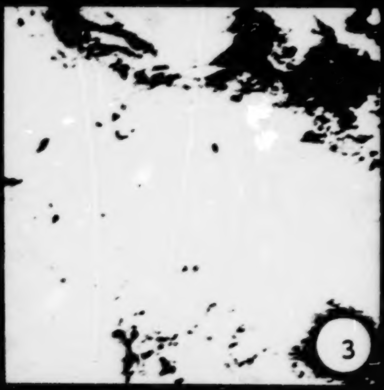
3

6

Satellite Imagery

March 24

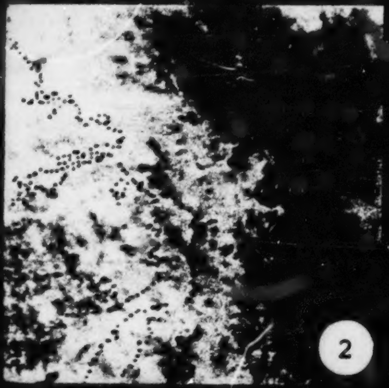




Satellite Imagery

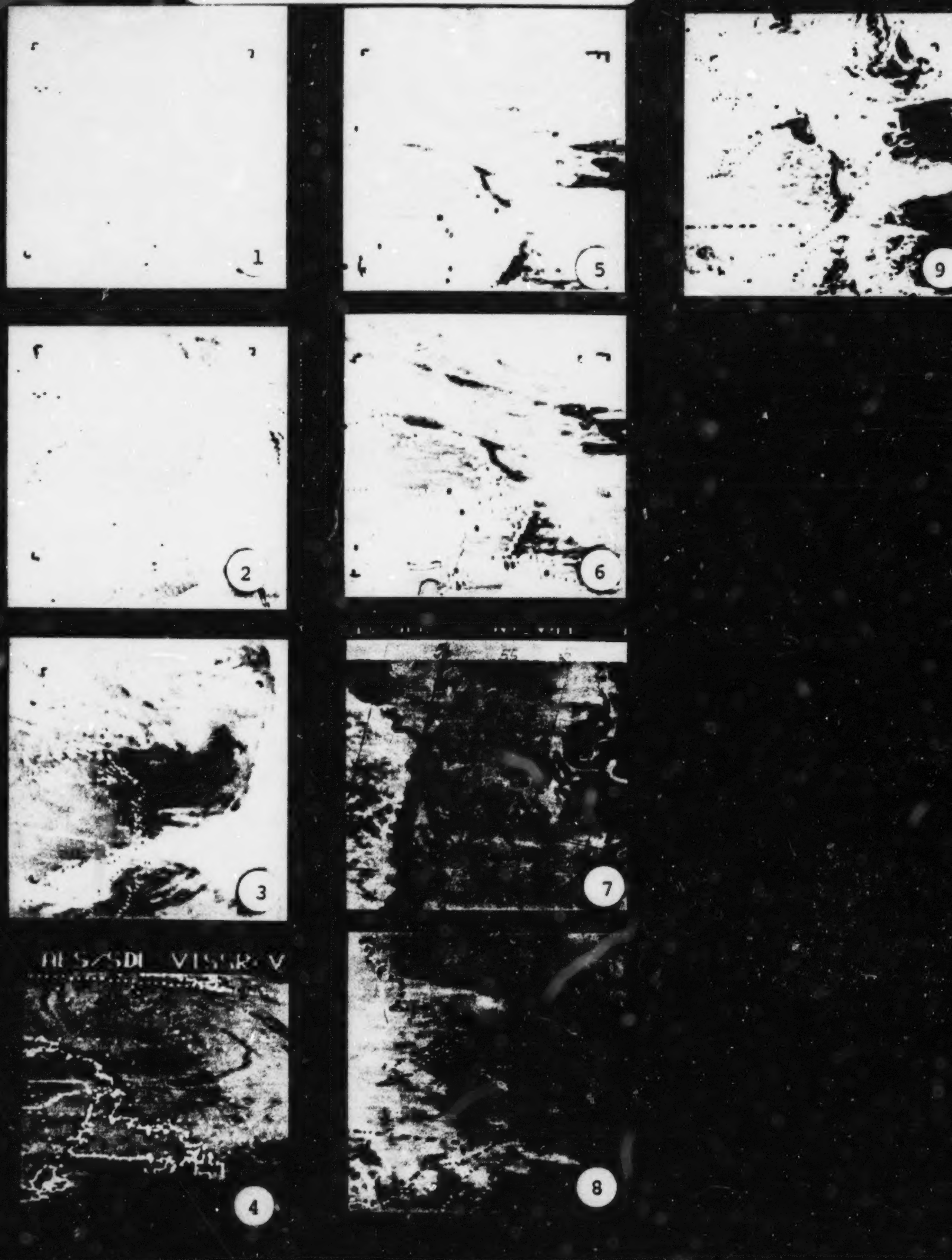
March 25

①


②

Satellite Imagery

March 26


1
2
3
AES/SDL VISSR V
4
5
6
7
8
9

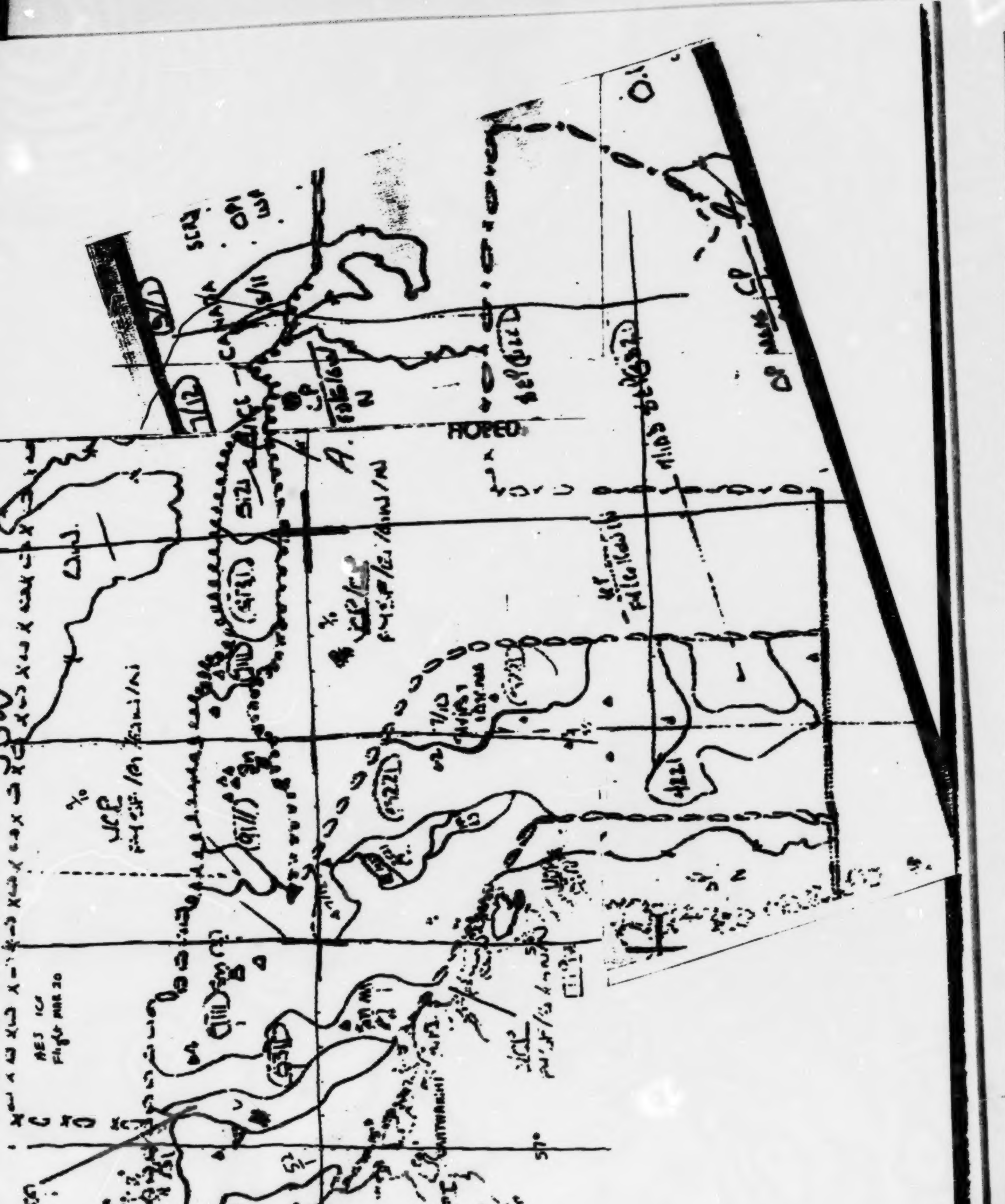
D

APPENDIX D

Atmospheric Environment Service

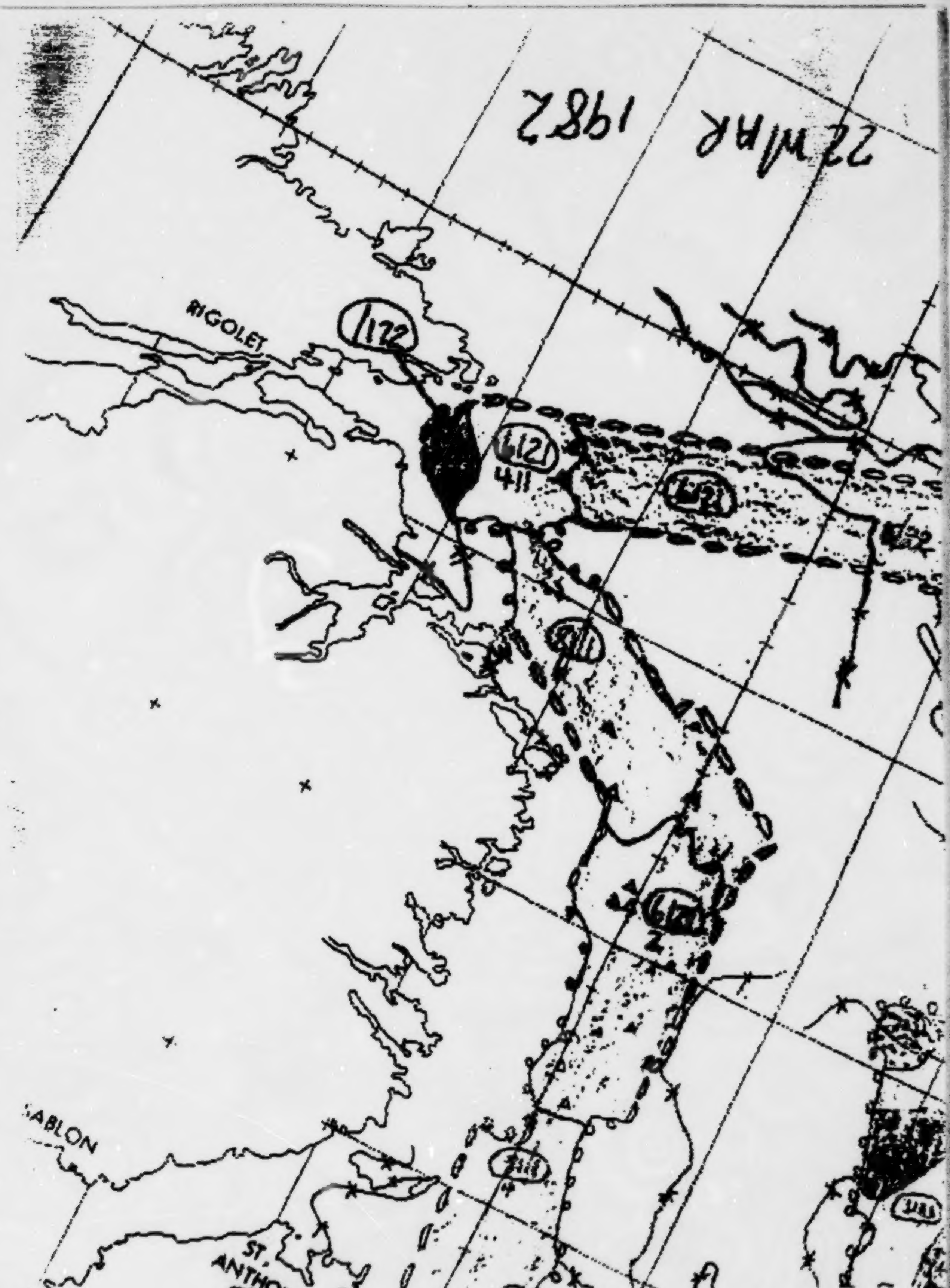
Aerial Ice Reconnaissance Charts

Note: The key for interpreting these charts is provided at the end of this appendix.


AES Ice
Flight MAR 20
CANADA
54N

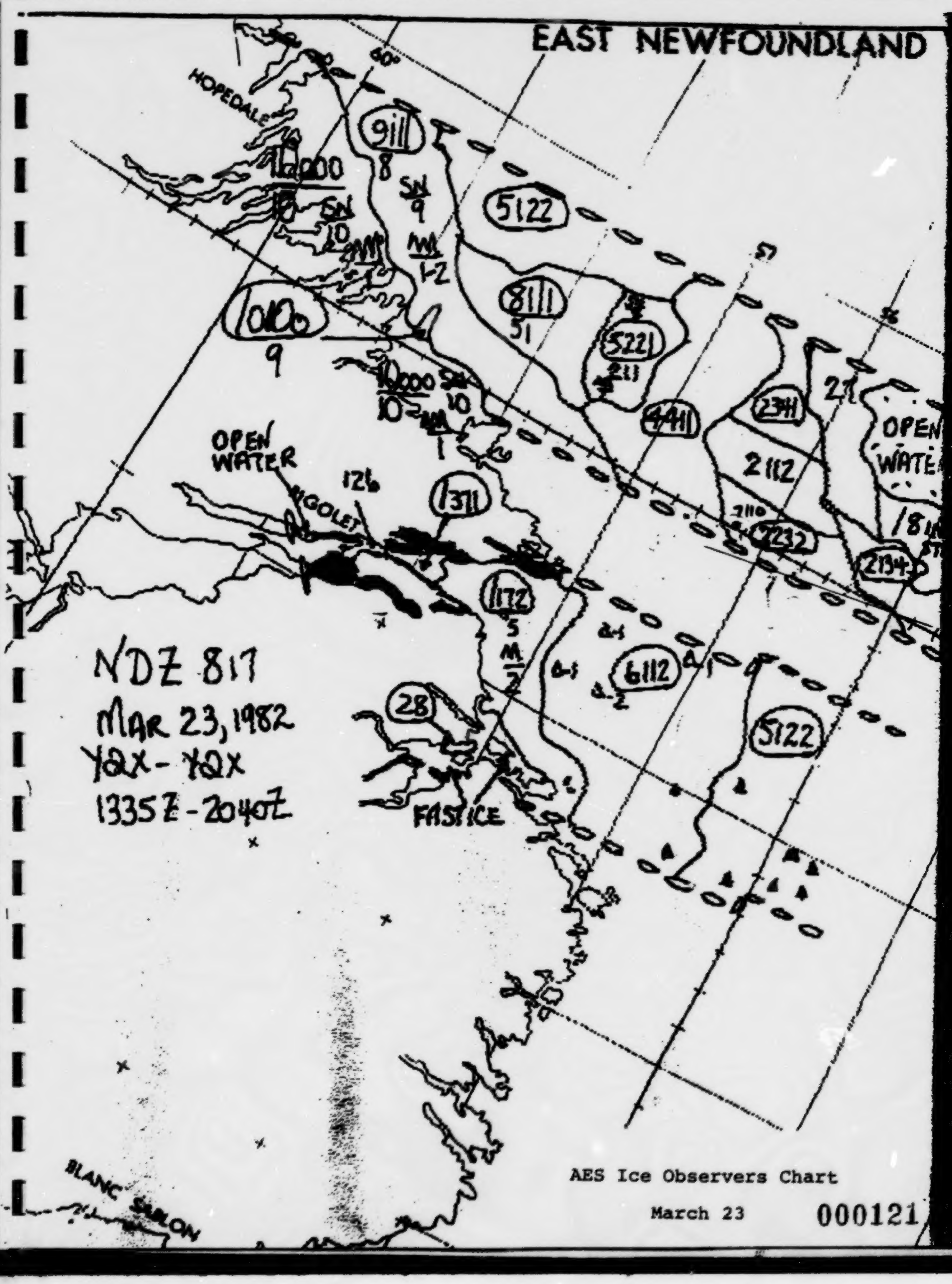
AES Ice Observers Chart

March 20


22MAR 1982
RIGOLET
1172
1121
411
ABLON
ST. ANTHONY
ICHE

AES Ice Observers Chart
March 22 000120

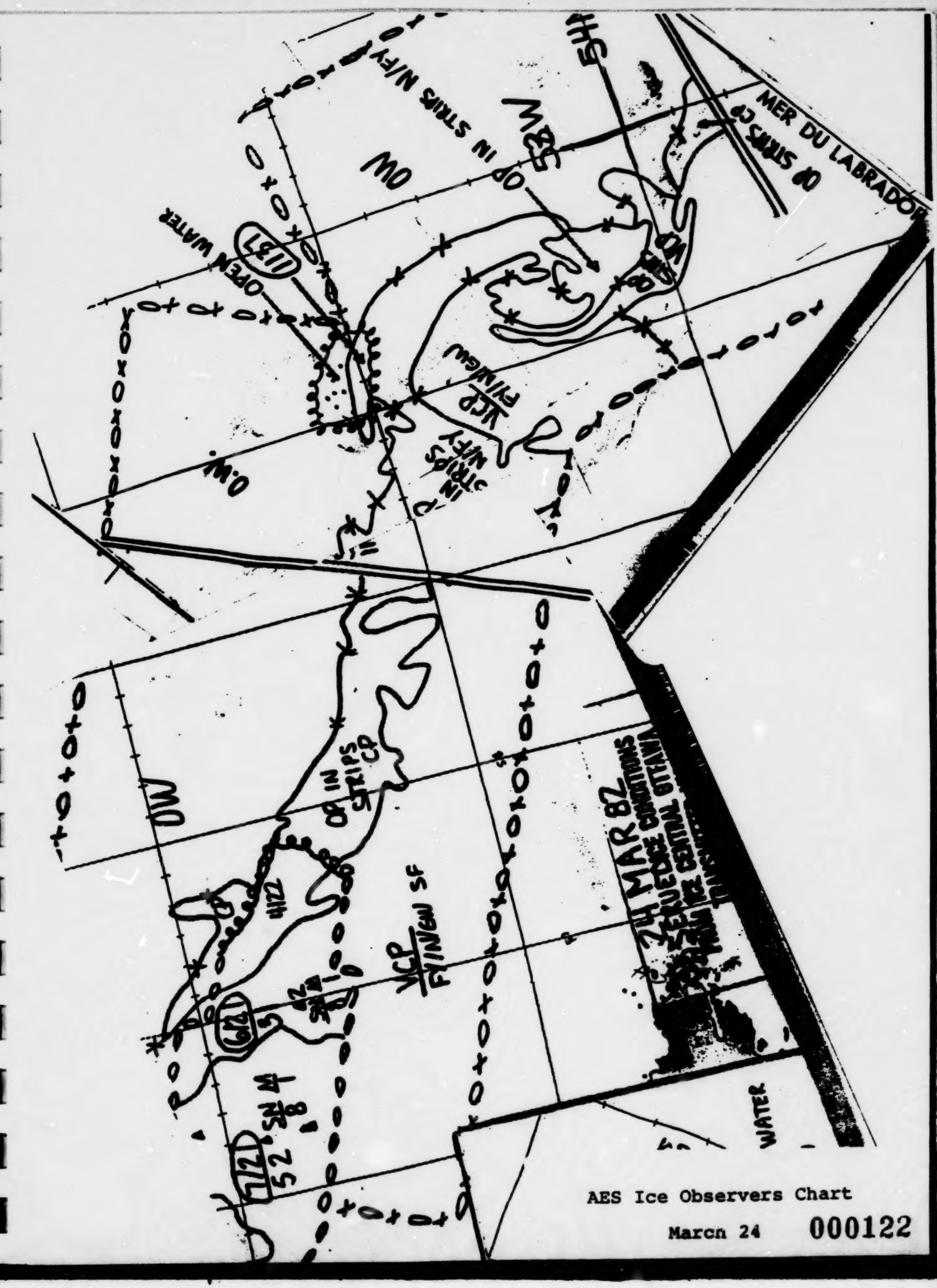
EAST NEWFOUNDLAND


60°
HOPEDALE
9111
8
10000
10
SN
9
SN
10
M
1-2
5122
8111
51
5221
211
10100
9
10000
10
SN
10
M
1
4411
2341
27
OPEN WATER
2112
2232
2134
OPEN WATER
RIGOLET
126
1371
1172
5
M
2
6112
5122
28
FAST ICE
BLANC SABLON

NDZ 817
MAR 23, 1982
YQX - YQX
1335Z - 2040Z

AES Ice Observers Chart

March 23 000121


MER DU LABRADOR
OP STRIPS CP
OP IN STRIPS N/FY
OW
5H
OPEN WATER
1137
VCP
FY/NI/GW
OP IN STRIPS N/FY
O.W.
OP IN STRIPS CP
OW
24 MAR 82
SEA ICE CONDITIONS
ICE CENTRAL OTTAWA
VCP
FY/NI/GW SF
4122
6121
7121
52
SN M
WATER

AES Ice Observers Chart

March 24 000122

KEY TO ICE SYMBOLS

CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or greater}}$$

$$\frac{\text{Cmy Csy Cfy Cgy Cgw Cg Cn}}{\text{Nmy Nsy Nfy Ngw Ng Nn}}$$

Example $\frac{20.3410}{1 \quad 23}$

2-2/10's Multi Year of which
1 1/10 is Medium Floe or Greater
0- No Second Year
. - Decimal Point
3 - 3/10's First Year of which
2 2/10's is Medium Floe or greater
4 - 4/10's Grey White of which
3 3/10's is Medium Floe or greater
1 - 1/10 Grey , no Mediam Floe or greater
0 - No New

SNOW COVER

Sn/(n)

(n) tenths on ice

TOPOGRAPHY

$\frac{\wedge\wedge}{(n)}$ Rafted ice

$\frac{\wedge\wedge\wedge}{(n)}$

SURFACE FEATURES

Sn/Re Rd Hy Pd Th+ F

$\frac{\cap\,\cap}{(n)}$ Hummocks

(n) number of tenths

STAGE OF MELTING

$$\frac{\text{Pd}}{(n)\ (n)\ \text{Th}+\ (n)\ \ \text{F}}$$

(n)= tenths on ice
(n) th = tenths thaw holes
(n)F = tenths frozen

e.g. 6/120
6- 6/10 Snow Cover
/ -Slant
1 - 1/10 Rafting
2 - 2/10 Ridging
0 - No Hummocks
1 - 1/10 Puddling

THICKNESS OF ICE AND SNOW

T/n · S/n (n) – nearest inch

ICE OF LAND ORIGIN

△ - (n) Icebergs
⌓ - (n) Bergy Bits and growlers
Optional : (n) number in area

WATER FEATURES

-+-+-+- Creek

═ Lead

⬭ Polynye

UNDER CAST

⌒⌒ Limits

BOUNDARY

——— Observed visually

-‖—‖—‖- Observed by radar

- - - - - - Assumed

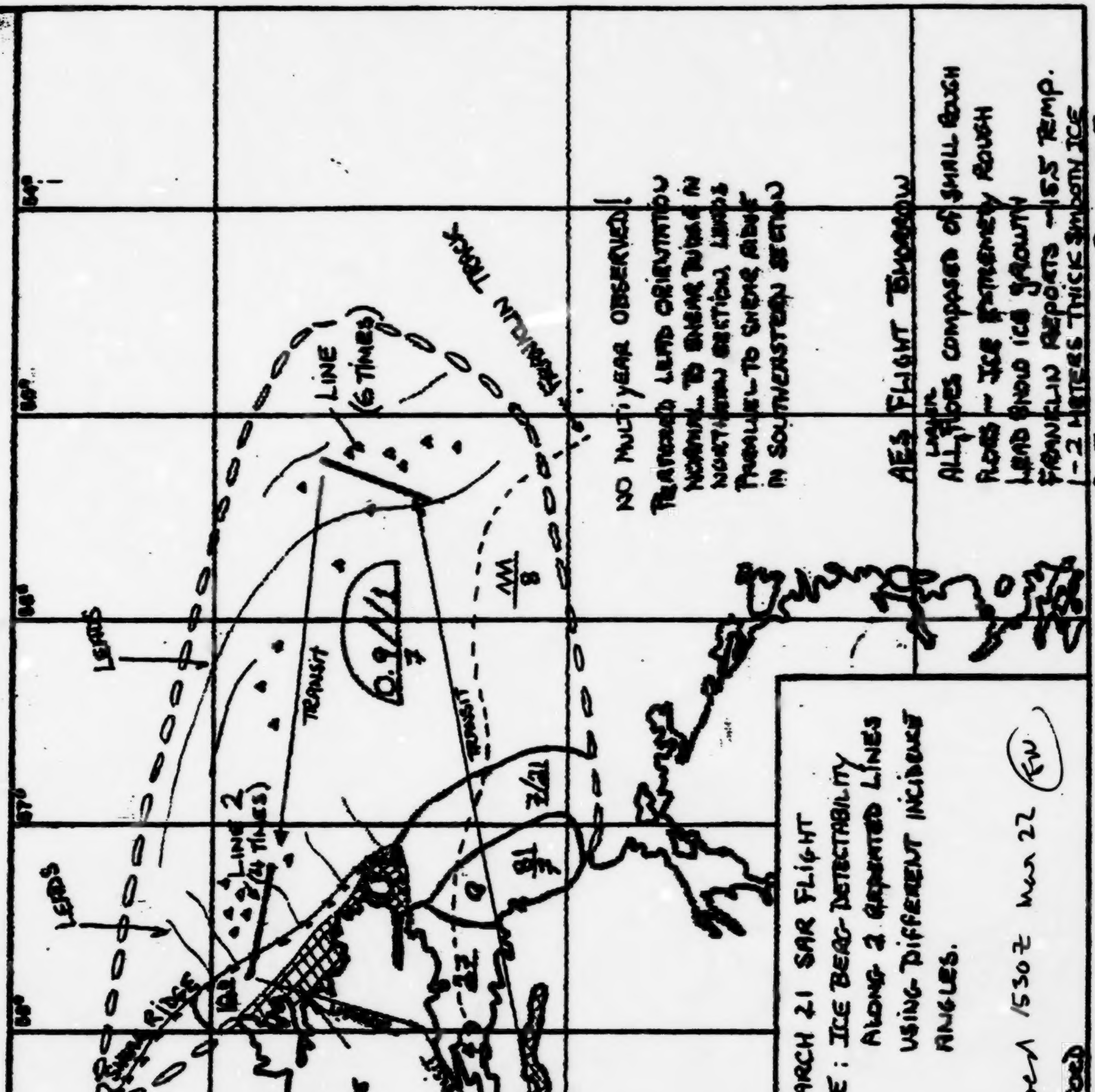
○ ○ ○ Limit of Observed date

○○○ Limit of radar date

APPENDIX E

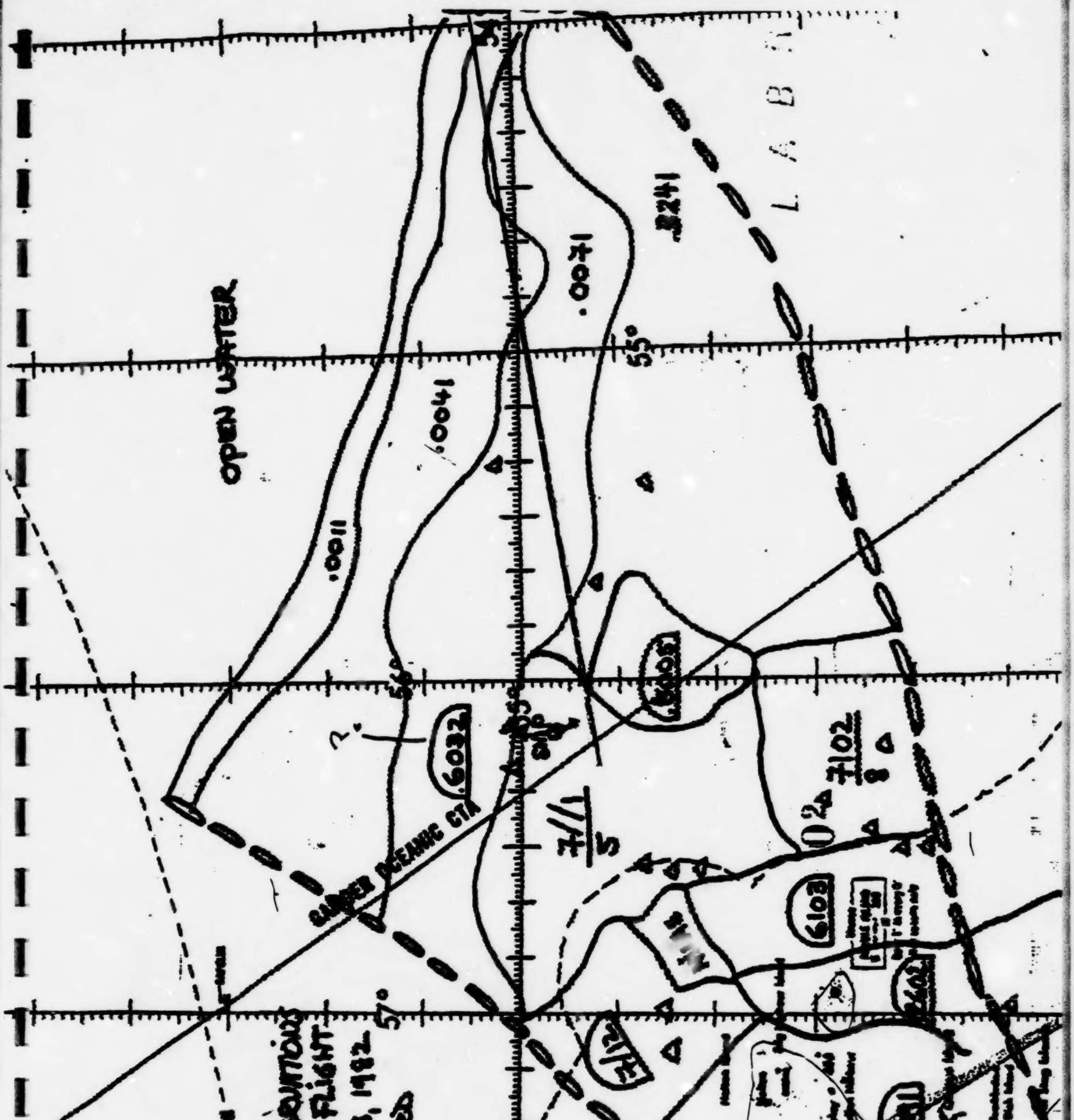
Ice Charts prepared by Intera Ice Observer

Note: The key for interpreting these charts is included at the end of this appendix.


SUN MARCH 21 SAR FLIGHT
OBJECTIVE: ICE BERG-DETECTABILITY ALONG 2 ORIENTED LINES USING DIFFERENT INCIDENT ANGLES.
Received 1530Z Mar 22 RW
J.R. CRAWFORD
NO MULTIYEAR OBSERVED!
FEATURED LEAD ORIENTATION NORMAL TO SHEAR ZONE IN NORTHERN SECTION, LEADS PARALLEL TO SHEAR ZONE IN SOUTHEASTERN SECTION
AES FLIGHT TOMORROW
LARGE ALL FLOES COMPOSED OF SMALL ROUGH FLOES - ICE EXTREMELY ROUGH
LEAD BOUND ICE GROWTH
FRANKLIN REPORTS -15.5 TEMP.
1-2 METERS THICK SMOOTH ICE
3-5 METERS THICK ROUGH ICE
LEADS
LEADS
RIDGE
LINE 2 (4 TIMES)
LINE (6 TIMES)
TRANSIT
TRANSIT
TRACK
FRANKLIN TRACK
FAST ICE
0.9/1/1
7
9/1
8

Ice Chart Prepared by
INTERA Ice Observer

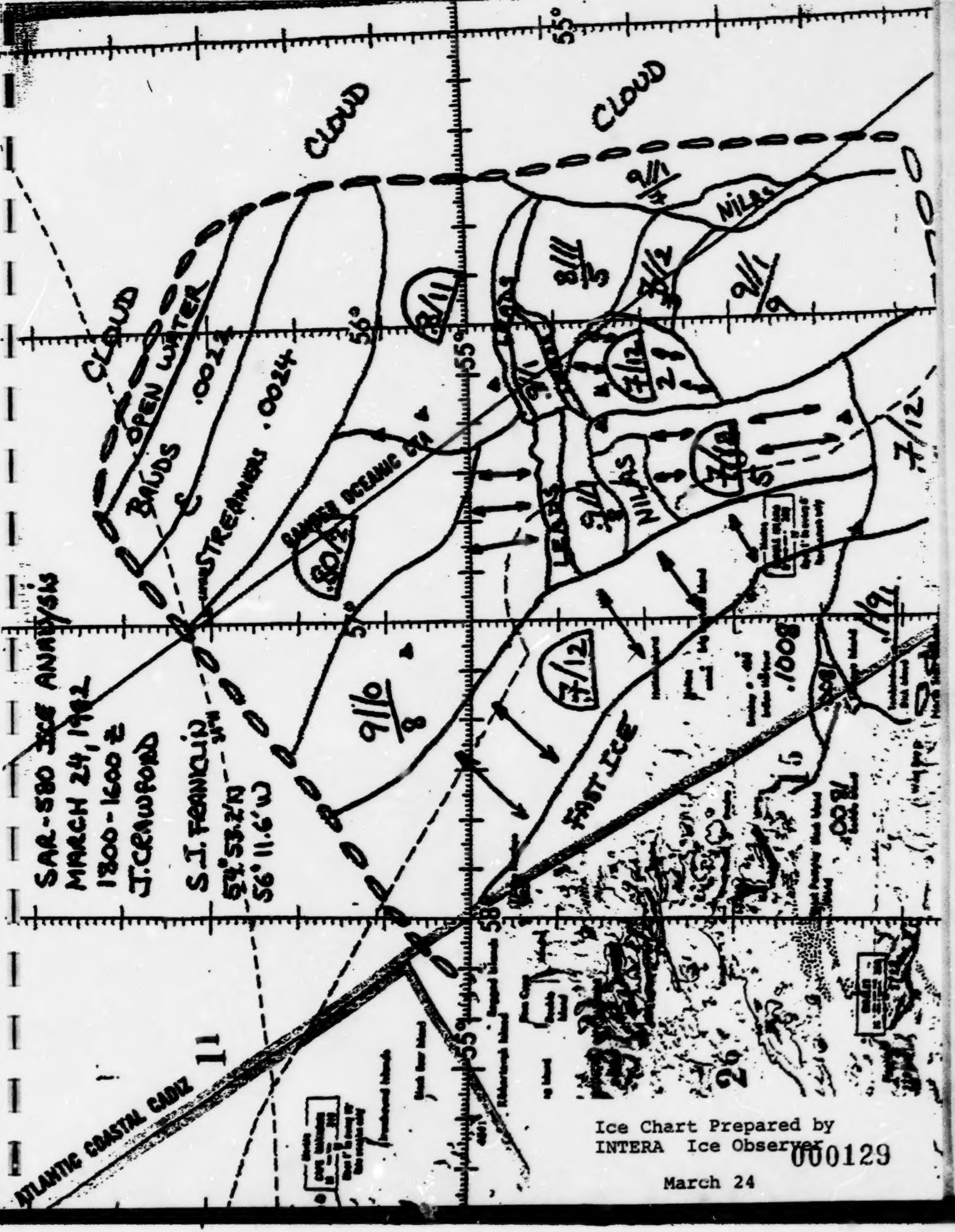
March 22



OPEN WATER
L A B R
.0011
.0041
.0071
.8241
55°
56°
57°
58
54
GARDNER OCEANIC CTA
6005
6032
7/11
5
7102
8
6103
6602
6611

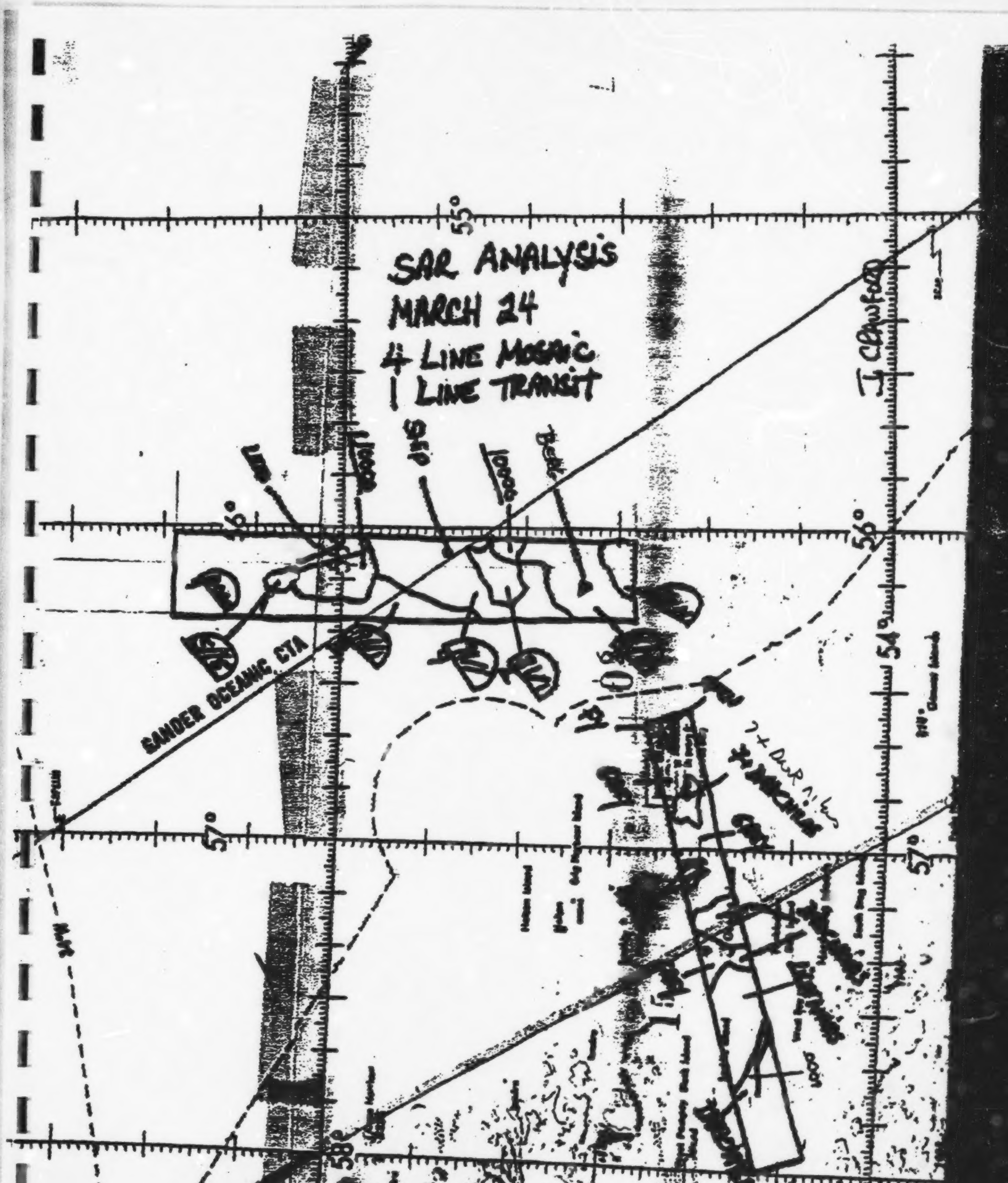
ICE OBSERVATIONS
SAR-580 FLIGHT
MARCH 23, 1982
J. CRAWFORD

Ice Chart Prepared by
INTERA Ice Observer


SAR-580 ICE ANALYSIS
MARCH 24, 1982
1800-1600 Z
J. CRAWFORD
S.I. FRANKLIN
54°53.2'N
56°11.6'W
CLOUD
CLOUD
CLOUD
OPEN WATER
BANDS
.0022
STREAMERS
.0024
SAMPLE OCEANIC CM
80/12
9/6/8
8/11
9/11
9/11/3
8/11/5
9/11/9
7/12
7/12
7/12
7/12
1/9
LEADS
NILAS
NILAS
FAST ICE
.1008
ATLANTIC COASTAL CADIZ
55°
56°
58°
59°

Ice Chart Prepared by
INTERA Ice Observer

March 24


55°
56°
57°
58°
54°
GANDER OCEANIC CTA
10000
Ship
10000
Berg
J. CRAWFORD

SAR ANALYSIS
MARCH 24
4 LINE MOSAIC
1 LINE TRANSIT

Ice Chart Prepared by
INTERA Ice Observer

March 24

KEY TO ICE SYMBOLS

CONCENTRATION AND SIZE BY AGE

$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or greater}}$

$\frac{\text{Cmy Csy Cfy Cgy Cgw Cg Cn}}{\text{Nmy Nsy Nfy Ngw Ng Nn}}$

Example $\frac{20.3410}{1 \quad 23}$

2-2/10's Multi Year of which
1 1/10 is Medium Floe or Greater
0- No Second Year
. - Decimal Point
3 - 3/10's First Year of which
2 2/10's is Medium Floe or greater
- 4/10's Grey White of which
3/10's is Medium Floe or greater
- 1/10 Grey , no Mediam Floe or greater
- No New

SNOW COVER

Sn/(n)

(n) tenths on ice

TOPOGRAPHY

$\frac{\text{A A}}{\text{(n)}}$ Rafted ice

$\frac{\text{AAA}}{\text{(n)}}$

SURFACE FEATURES

Sn/Re Rd Hy Pd Th+ F

$\frac{\cap\cap}{\text{(n)}}$ Hummocks

(n) number of tenths

STAGE OF MELTING

$\frac{\text{Pd}}{\text{(n) (n) Th+ (n) F}}$

(n)= tenths on ice
(n) th = tenths thaw holes
(n)F = tenths frozen

e.g. 6/120
6- 6/10 Snow Cover
/ -Slant
1 - 1/10 Rafting
2 - 2/10 Ridging
0 - No Hummocks
1 - 1/10 Puddling

THICKNESS OF ICE AND SNOW

T/n · S/n (n) - nearest inch

ICE OF LAND ORIGIN

△ - (n) Icebergs
⏢ - (n) Bergy Bits and growlers
Optional : (n) number in area

WATER FEATURES

+++++ Creek

═ Lead

⬭ Polynye

UNDER CAST

≈ Limits

BOUNDARY

———— Observed visually

—‖—‖—‖— Observed by radar

- - - - - - Assumed

○ ○ ○ Limit of Observed date

○○○ Limit of radar date

000131

APPENDIX F

Ice and Weather Reports

From

The CCGS Franklin

Note: The key for interpreting the ice section of these reports is included at the end of this appendix.

13

```
 041356SMVD2 KWBC 211200
BBXX
CGDT 21124 99539 70559 42998 83311 11138 2119/ 40168 52010 80007
 22272 071// 31340 10/50 20056.803//=
VGLB 21124 99486 70681 42/99 20607 1103/ 4015/=
CGBR 21124 99476 70579 41/97 50312 1102/ 4010/ 77171=
CG2835 21124 99469 70527 41/94 81107 11020 2105/ 40125 50005 77102
 88/// 22282 01010=
URJQ 21121 99432 70498 42897 10708 10020 40050 57016 7//// 81004
 22211 00042 20201 3//// 4//// 5//// 60000 00000=
```

```
SIVD1 CYQX 211500
BBXX
CGDT 21154 99543 70563 42998 33207 11145 2119/ 40179 51011 80008
22272 ICE 071// 31340 10/50 20056 803//=
```

```
SMVD1 CYQX 211800
BBXX
CGDT  21184 99544 70568 42998 23209 11150 2119/ 40177 58003 80008
22272 071// 2/320 31/40 72055 804//=
SMVD1 CYQX 221200
BBXX
CGDT 22124 99540 70588 42998 10807 11252 2130/ 40154 55003 80001
22261 ICE 08000 80200 00300 83407 805//=
```

```
SIVD1 CYQX 221500
BBXX
CGDT 22154 99540 70590 42998 12311 11250 2128/ 40150 57004 80001
22261 ICE 08000 80200 00300 83406 806//=
```

```
SMVD1 CYQX 221800
BBXX
UHPO 22181 99426 70432 41597 83211 10112 49998 52028 70326 8872/
22263 00140 20908=
VOBJ 22184 99462 70506 42/98 81310 1101/ 4005/=
CGBT 22184 99540 70590 42998 52503 11156 2120/ 40118 58032 80006
22251 ICE 08000 80200 00300 83407 805//=
```

```
21402142SIVD1 CYQX 222100
BBXX
CGDT  22214 99540 70589 42998 80305 11165 2122/ 40092 57026 80007
22221 08000 80200 00300 83407 806//=
SMVD1 CYQX 231200
BBXX
CGDT 23124 99550 70560 42698 32502 11092 2114/ 400065 53001 81571
22211 ICE 06310 01420 10//0 90057 804//=
```

```
SIVD1 CYQX 231500
BBXX
CGDT 23154 99550 70562 42998 82004 11079 2113/ 40063 58002
80007 22251 ICE 07110 00320 10//0 90057 804//=
```

```
SMVD1 CYQX 231800
BBXX
CGDT  23184 99550 70562 42998 82404 11068 2112/ 40055 55008 8008
22200 07110 00320 10//0 90057 804//=
CGDR  23184 99476 70579 42/98 83215 1101/ 4002=
VGFP  23184 99453 70558 41/98 73120 1001/ 4002/=
```

```
SIVD1 CYQX 232100
BBXX
CGDT 23214 99550 70562 42998 82703 11080 2112/ 40060 51005 81037
22200 ICE 07110 00320 10//0 90057 804//=
```

7110 , 33

```
SMUD1 CYQX 241200
33XX
CGDT  24124 99549 70562 42398 82912 11096 2113/ 40112 51018 83107
22231 07110 00320 10//0 90057 804//=
```

```
GA*SA INPUT
              241300
```

```
SIVD1 CYQX 241500
33XX
CGDT 24154 99549 70562 42399 32916 11101 2112/ 40129 51017 83100
22231 ICE 07110 00320 10/40 90057 804//=
```

```
SIVB1 CYQX 242100
33XX
CGDT 24214 99548 70561 42898 12909 11101 3114/ 40148 51014 81070
22231 ICE 07101 00320 10/41 44057 804//=
SMVD1 CYQX 251200
BBXX
CGDT 25124 99549 70561 42998 52114 11051 2107/ 40094 56005 80001
22241 ICE 07101 00320 10/41 44057 804//=
```

```
SMVD1 CYQX 251500
BBXX
CGDT 25154 99548 70556 42998 31915 11032 2106/ 40099 51006 80001
22232 ICE 05302 00220 20//4 70056 804//=
```

```
SMVD1 CYQX 251800
BBXX
CGDT 25184 99544 70545 42998 11918 11019 2104/ 40103 50004 80001
22233 01015 ICE 04131 00220 10//4 70056 80452=
SMVD1 CYQX 261200
BBXX
CGDT 26124 99508 70535 42598 81920 10010 2103/ 40180 52034 885//
22253 ICE 04150 00200 00/20 10005 803//=
```

```
SMVD1 CYQX 261800
BBXX
CGDT  26184 99506 70532 42998 11909 10020 2000/ 40211 51012 80001
22241 04131 00200 00//0 10015 803//=
```

CHAPTER IV

SHIPBOARD ICE OBSERVATIONS

4. OBSERVATIONAL TECHNIQUES FROM SHIPBOARD.

4.1. Shipboard observers are in a position to examine closely and make detailed periodic observations of ice conditions immediately around their vessel regardless of the weather. They can determine accurately the texture and solidity of ice, variations in thickness, snow cover, state of deterioration and other features requiring actual contact with the ice. Whenever it is possible for the observer to get on to the ice, he should make accurate measurements of heights of ridges, snow cover and ice.

4.1.1. Shipboard observers are limited to small areas immediately surrounding their stations and the data therefore is local in nature. Although the shipboard observer's field of view is limited and much of that subject to distortion, he can estimate accurately the total ice coverage, the type of ice, the size and orientation of water features within several thousand yards of the ship, with the aid of radar his horizon may be considerably extended, thus enabling him to fill the gaps in the airborne observer's report.

4.1.2. The helicopter has done much to enlarge the ship observers horizon but helicopter observations must still be considered tactical operations proving short range reconnaissance.

4.2. OBSERVERS RESPONSIBILITIES

4.2.1. Providing it does not interfere with ice observing duties, the ice observer will make, record, and arrange for transmission of six complete synoptic weather observations daily at 1200, 1500, 1800, 2100, 0000 and 0300 GMT. These are observed and recorded in accordance with the procedures outlined in MANMAR. It is most important that these reports be made on a continuous basis in the Arctic and sub-Arctic waters, because of their great operational and climatological significance in these little known areas. Observations should be made irrespective of the vessels position. Where the ice observer is off duty or unable to make a weather observation because of duties pertaining to ice, then the ship's officers are to assist him by taking the observation and transmitting the report as noted in Coast Guard Service Instruction 10.18. Normally the ship's officers will take the 0600 and 0900 GMT synoptic. In this connection, the ice observer will provide instruction and guidance to the ship's officers in observing and coding techniques.

4.2.2. When more than one icebreaker with Ice Observers assigned are operating within sight of one another, only one weather/ice synoptic is required from the ships. The Ice Observers on the icebreakers not taking an observation will indicate in the weather logbook that this particular observation was taken by the other ship (name) within sight. For continuity of records the observed ice data should be transferred by radio or other means to the off-duty observer at their conveniences.

4.2.3. For operations in the Arctic and Sub-Arctic, one daily weather/ice observation at either 1200Z or 1500Z will be transmitted while at anchor or discharging cargo at all ports even if weather facilities are available. (e.g. Cambridge Bay, Clyde River or Resolute). At ports of call where no weather facilities exist the main synoptics at 0000Z, 1200Z and 1800Z will be taken and transmitted.

4.2.4. The ice observer will be responsible for the ice observations taken on the ship. These are in three forms: technical reports, coded reports and canice on request from the Master of the ship.

4.2.5. The observers assigned to icebreakers are responsible for arranging the running maintenance of the radio facsimile machine on board the ship, as set forth in Section 24, of M.S.C. Circular 2337, FAXPRO.

4.2.6. The observer will be responsible for the maintenance and care of all meteorological instruments on board the ship. At the end of the patrol, all instruments and supplies remain with the ship, with an inventory forwarded to the nearest Port Meteorological Officer, copy to the Director, Meteorological Branch.

4.3. SHIPBOARD ICE OBSERVATIONS

4.3.1. The shipboard ice observations will be made on the revised form 2318, M.S.C. Shipboard Ice Report. The log is designed primarily for use by ship's observers.

4.3.1.1. When operating in ice, the observer will make, record and arrange the transmission of coded ice reports. The observation time of the coded ice report will be the same as the weather synoptic report. This schedule of observations should continue even though the ship is hove to or beset in ice. When the ship is in anchorages and harbours where shore personnel are reporting ice and weather observations, shipboard observations may be discontinued, except as in para. 4.2.3.

4.3.1.2. The coded ice report will be appended to the routine weather report preceded by the word "Ice" and followed by the last ~~four~~ five groups of revised form 2318 plus the supplementary groups as required. Under certain conditions, reports indicating the absence of ice may be as significant as reports made while operating in ice. Therefore, when no ice is present, the report will consist of the word "Ice" followed by the world "Nil", appended to the routine weather report.

4.4. THE SHIPBOARD CODE IN SYMBOLIC FORM

4.4.1. The complete coded ice report will be composed of the identifier "Ice" and five figure groups in the following orde.

ICE C_oC_{fy} $C_{gw}C_gC_n$ $N_1N_2R_eT_oP_d$ $T_eT_hT_fI_dB_t$

$W_fO_fF_iI_bI_TVI_{bi}$ $S_nT_sT_s$ 11000 $PL_oL_oL_oL_o$ $PL_oL_oL_oL_o$ 22000

$PL_oL_oL_oL_o$ $PL_oL_oL_oL_o$ 33000 $WL_oL_oL_oL_o$ $WL_oL_oL_oL_o$ 44000

$D_wL_oL_oL_oL_oD_1L_oL_oL_oL_o$ 55000 $D_iD_iD_iV_iV_i$ 66000 $D_cD_cD_cV_cV_c$

4.5. MEANING AND USE OF THE LETTERS OR SYMBOLS

4.5.1. **TABLE 1 - C_oC_{fy} $C_{gw}C_g$ C_n - N_1N_2** - Concentration and size ice is reported in terms of tenths of surface covered for each of the five age classes: Old Ice, First Year, Grey White, Grey and New Ice in that invariable order. If no ice is present Code Nil and end the report. The number of tenths of the larger size category (medium floe or greater) of the two oldest ages present ice reported in the second group using the same table.

4.5.2. TABLE 2 - R_e & I_t - RELIEF AND ICE THICKNESS

The vertical distance between the surface of sea ice above the water line is called "*Relief*". Icebergs and other ice of land origin have no part in this definition.

4.5.3. TABLE 3 - T_o - SURFACE FEATURES

Topography is a qualitative term used to describe the character of the ice surface. Various topographic features of sea ice are described in Chapter II. Code the most nearly representative feature and mention others in "Remark".

4.5.4. TABLE 4 - P_d - STAGE OF MELTING

Only the ice area is considered in determining the stage of melting. Puddles seldom cover more than 8/10 of the ice surface. In very rare instances, however, practically the entire surface of the ice may be covered. If code numbers 3, 2, or 1 clearly do not apply, then code number 4 (7/10 to 9/10 ice area puddles) will be used.

4.5.5. TABLE 5 - T_e - EXTENT OF TOPOGRAPHY

The coded value for reporting extent of topography will be the amount of the predominant Surface Feature (T_o) reported in Table 3.

4.5.6. TABLE 6 - T_h - HEIGHT OF TOPOGRAPHY

The height of topography will be the maximum height of the topography observed.

4.5.7. **TABLE 7 - T_f - TYPE OF FAST ICE**

These features should be reported whenever a ship is operating near coastlines.

4.5.8. **TABLE 8 - I_d - ICE DRIFT**

Whenever possible the ice drift will be reported and coded as in this table.

4.5.9. **TABLE 9 - B_t - TREND IN BEHAVIOR OF ICE**

Enter here the most dominant feature and code it according to this table.

4.5.10. **TABLE 10 - W_f - OPENINGS IN THE ICE**

Artificially broken cracks and leads, whether or not they have closed in the vessels wake, will not be considered. Newly frozen polynyi, leads or cracks, will be reported as though they were unfrozen.

4.5.11. **TABLE 11 - O_f - ORIENTATION OF OPENINGS IN THE ICE**

Enter here the dominant orientation of openings in the ice coded in Table 5. If the orientation is not obvious, the observer will report the direction from the ship that offers least obstruction to the line of sight. If only shore leads are present, their orientation will reported by using code number 5 to 8.

4.5.12. **TABLE 12 - F_i - FAST ICE**

All types of ice, either broken or unbroken, attached to shore, beached, stranded in shoal water, or attached to the bottom of shoal areas, are considered fast ice. Tidewater glaciers will be considered part of the land. With the code numbers 1, 2, and 3, water features as in Table 5 will have been reported; but with code number 4, water features may or may not have been reported.

4.5.13. **TABLE 13 - I_b - ICE OF LAND ORIGIN**

If a single or small number of ice fragments cannot be identified as growlers or ice cakes, they will be reported as growlers.

4.5.14. **TABLE 14 - V, W, D_w, D_l - VISIBILITY, WIDTH OF LEAD, LENGTH AND WIDTH OF POLYNYI**

The prevailing visibility will be coded. In the supplemental groups, the width of a lead, the length and width of a polynya will be coded from this table.

4.5.15. **TABLE 15 - I_{b1} - WATER SKY OR ICE BLINK**

The presence of either of these features will be coded from the table. If either feature is observed in two or more directions, the direction of the most prominent display of the feature should be reported. Additional information will be noted in "Remarks".

4.5.16. TABLE 16 - S_n - SNOW COVER

Depth of snow may be estimated by the ships observer or measured directly by parties on the ice. If snow thickness is not considered, other snow features will be coded. Additional notes will be mentioned in "Remarks".

4.5.17. WATER TEMPERATURE (°C)

nn No table is needed for this two-digit number. The water temperature will be entered in the two spaces provided to the nearest whole degree (celsius) as read. When the temperature is below 0° add 50 to the reading, ignoring the minus sign.

eg. temperature of - 1°C is coded as "51".

4.5.18. SUPPLEMENTAL GROUPS

Group Indicators	Groups Repeated as Required	
11000	$PL_aL_aL_aL_a$ $PL_oL_oL_oL_o$	*Positions of drift ice boundary*
22000	$PL_aL_aL_aL_a$ $PL_oL_oL_oL_o$	Positions of fast ice boundary
33000	$WL_aL_aL_aL_a$ $WL_oL_oL_oL_o$	*Width and position of lead*
44000	$D_wL_aL_aL_aL_a D_lL_oL_oL_oL_o$	*Dimensions and positions of polynyi*
55000	$D_iD_iD_iV_iV_i$	*Direction and Speed of ice drift*
66000	$D_cD_cD_cV_cV_c$	*Direction and speed of current*

4.5.18.1. KEY OF ELEMENTS

P	Point of drift or fast ice boundary , coded "O"
W	Width of lead (Table 9)
D_w	Width of polynya (Table 9)
D_l	Length of Polynya (Table 9)
$L_aL_aL_aL_a$	Latitude in degrees and minutes
$L_oL_oL_oL_o$	Longitude in degrees and minutes
$D_iD_iD_i$	Direction towards which ice is moving in degrees
V_iV_i	Speed of ice drift in knots & tenths of knots
$D_cD_cD_c$	Direction towards which current is moving in degrees
V_cV_c	Speed of current in knots and tenths of knots

4.6. EXPLANATIONS ON THE USE OF SUPPLEMENTAL GROUPS

4.6.1. The area covered will be along the vessels course from the last transmitted ice observation. If the ship is making little headway, the adding of supplemental groups generally will not be necessary. Information supplied by aerial observers will be included in these groups.

4.6.2. To report the position of a drift ice boundary the supplemental group 11000, followed by a series of points along the boundary, is used. The first symbol "P" for both the latitude and longitude groups will be coded "O".

4.6.3. The same procedure will be followed in reporting fast ice boundary, except that the initial group will be "22000".

4.6.4. If a lead is present, the introductory group will be "33000", followed by a series of points along the middle of the lead, but the first symbol "W" for both the latitude and longitude groups, includes the entire width of the lead at the point and will be coded as found in Table 9.

4.6.5. Polynyi will be introduced by the group "44000". The first symbol of the next group "D_w" will be the width of the polynya coded as found in Table 9. The latitude will be that of the centre of the polynya. In like manner in the next group the initial symbol, "D_l", will show the length of the polynya followed by the longitude of its centre.

4.6.6 Ice drift information will be introduced by the group "55000". The first three symbols of the next group $D_iD_iD_i$ will be the direction to the nearest degree toward which the ice is moving, i.e. 6 degrees, 60 degrees, or 260 degrees would be encoded as follows: 006, 060, 260; when the speed exceeds 9.9 knots, 500 is added to these figures. The last two symbols of the group V_iV_i will state the speed of the ice drift in knots and tenths up to 9.9 and to the nearest knot after that. When the speed exceeds 9.9 knots 500 will be added to the direction prior to encoding $D_iD_iD_i$ as stated above.

4.6.7. Current information will be introduced by the group "66000". The first three symbols of the next group $D_iD_iD_i$ will be the direction to the nearest degree towards which the current is moving, i.e. 6 degrees, 60 degrees, 260 degrees would be encoded as follows: 006, 060, 260; when the speed exceeds 9.9 knots 500 is added to these figures. The last two symbols of the group V_iV_i will state the speed of the current in knots and tenths up to 9.9 and to the nearest knot over that. When the speed exceeds 9.9 knots 500 will be added to the direction prior to encoding $D_iD_iD_i$ as stated above.

4.7. SAMPLE REPORT

4.7.1. A sample coded observation complete with supplemental groups, and a decode of the report follows:

```
ICE      06200    20448    21034    43156    80451
11000    07404    06020    07414    05945    07431
05945    33000    67451    65958    77513    76100
```

(06200): (06200) no old ice, 6 tenths first year ice, 2 tenths grey white ice, no grey ice and no new ice: (20448): (20) two tenths of the oldest ice (first year) is composed of floes of medium size or greater and none of the grey white floes are this large; (4) the relief of the ice is 12-18 inches above water line; (4) weathered ridges; (8) puddles are frozen; (21034): (2) 3 tenths of weathered ridges, (1) maximum height of ridges 6 feet, (0) no fast ice, (3) ice drift to E, (4), ice drifting away; (43156): (4) leads in combination with cracks, (3) lead oriented E-W, (1) shore entirely clear, (5) less than 20 icebergs, (6) ice thickness 2-3 feet; (80451); (8) visibility 10-25 miles (0) no water sky or ice blink, (4), 4 inches to less than 6 inches, (51), water temperature -1°C; (11000) positions of drift ice boundary follow: (07404 06020): (0) first digit in each group is "0"; (7404-6020) position 7404/6020 (other points) 7414/5945 7431/5945; (33000): width and position of lead follow; (67451-65958) (6-first digit in each group) lead 2-5 miles wide; (7451/5958 of reported width; and similarily for 77513 76100.

4.8. SHIPBOARD ICE REPORT CODE TABLES

TABLE 1 – Concentration and Size ($C_eC_{fy}C_{gw}C_gC_n$) (N_1N_2)

No sea ice	0
1/10	1
2/10	2
3/10	3
4/10	4
5/10	5
6/10 or 7/10	6
8/10 or 9/10	7
10/10	8
Not determined	/

TABLE 2 – Relief and Ice Thickness (R_a) (I_t)

No sea ice	0
Less than 3 in.	1
3 to 6 in.	2
6 to 12 in.	3
12 to 18 in.	4
18 in to 2 ft.	5
2 to 3 ft.	6
3 to 5 ft.	7
5 to 8 ft.	8
Greater than 8 ft.	9
Not determined	/

TABLE 3 – Surface Features (T_s)

Level ice	0
Rafted ice/Finger rafted ice	1
Hummocks	2
New ridges	3
Weathered ridges	4
Very weathered ridges	5
Aged ridges	6
Consolidated ridges	7
Standing floes	8
Undetermined or unknown	/

TABLE 4 – Stage of Melting (P_d)

Ice without puddles	0
Rotten, disintegrating ice	1
Puddles joined, extensive cracking	2
Thaw holes	3
Puddles - 7/10 to 9/10 ice area	4
Puddles - 4/10 to 6/10 ice area	5
Puddles - 1/10 to 3/10 ice area	6
Puddles - less than 1/10 ice area	7
Puddles frozen	8
Not determined	/

TABLE 5 – Extent of Topography (T_e)

No topography	0
1/10 - 2/10	1
3/10	2
4/10	3
5/10	4
6/10	5
7/10	6
8/10	7
9/10	8
10/10	9
Undetermined or unknown	/

TABLE 6 – Height of Topography (T_h)

0-3 feet	0
6 feet	1
9 feet	2
12 feet	3
15 feet	4
18 feet	5
21 feet	6
24 feet	7
27 feet	8
30 feet or more	9
Undetermined or unknown	/

4.8. (cont'd.)

TABLE 7 – Type of Fast Ice (T_f)

No fast ice	0
Young coastal ice	1
Young fast ice	2
First year fast ice	3
Second year fast ice	4
Multi year fast ice	5
Ice foot	6
Grounded ice	7
Stranded ice	8
Grounded Hummock	9
Undetermined or unknown	/

TABLE 8 – Ice Drift (I_d)

No ice drift	0
Ice drift to N	1
Ice drift to NE	2
Ice drift to E	3
Ice drift to SE	4
Ice drift to S	5
Ice drift to SW	6
Ice drift to W	7
Ice drift to NW	8
All ice motionless	9
Undetermined or unknown	/

TABLE 9 – Trend in Behavior of Ice (B_t)

No change	0
Ice situation improving (for navigation)	1
Ice situation worsening (for navigation)	2
Ice breaking up	3
Ice opening or drifting away	4
Ice increasing	5
Ice freezing together	6
Ice drifting in	7
Ice under pressure	8
Ice hummocking or screwing	9
Undetermined or unknown	/

TABLE 10 – Opening in the Ice (W_f)

No sea ice	0
Ice in belts and patches	1
Ice evenly distributed	2
Polynya(s) in combination with leads and cracks	3
Lead(s) in combination with cracks	4
Single polynya	5
Single lead	6
Two or more cracks	7
Single crack	8
No water features	9
Undetermined or unknown	/

TABLE 11 – Orientation of water Features (O_f)

No distinct orientation	0
Major axis of feature	
Oriented N–S	1
Oriented NE–SW	2
Oriented E–W	3
Oriented SE–NW	4
Parallels shore to N	5
Parallels shore to E	6
Parallels shore to S	7
Parallels shore to W	8
Undetermined or unknown	/

TABLE 12 – Fast Ice (F_i)

Shore not observed	0
Shore entirely clear	1
Ice blocking less than ½ shore	2
Ice blocking more that ½ shore but with openings	3
Ice blocking entire shore	4
Undetermined or unknown	/

4.8. (cont'd.)

TABLE 13 – Ice of land origin (I_b)

No land ice	0
Less than 100 growlers	1
100 or more growlers	2
Less than 50 bergy bits	3
50 or more bergy bits	4
Less than 20 ice bergs	5
20 or more icebergs	6
Belt(s) of icebergs, bergy bits, growlers	7
Not determined	/

TABLE 14 – Visibility & Dimension ($V, W, D_w D_l$)

Less than 50 yards	0
50 to 200 yards	1
200 yards to ¼ naut. mile	2
¼ to ½ naut. mile	3
½ to 1 naut. mile	4
1 to 2 naut. miles	5
2 to 5 naut. miles	6
5 to 10 naut. miles	7
10 to 25 naut. miles	8
25 or more naut. miles	9

TABLE 15 – Water Sky & Ice Blink (I_{bl})

Not present	0
Ice blink to N	1
Ice blink to E	2
Ice blink to S	3
Ice blink to W	4
Water sky to N	5
Water sky to E	6
Water sky to S	7
Water sky to W	8
Frost smoke	9
Undetermined or unknown	/

TABLE 16 – Snow Cover (S_n)

Bare ice or trace	0
Less than 1 inch	1
1 – Less than 2 inches	7
2 – Less then 4 inches	3
4 – Less than 6 inches	4
6 – Less then 10 inches	5
10 – Less than 20 inches	6
20 – Less than 40 inches	7
40 – Less than 80 inches	8
80 or more inches	9
Undetermined or unknown	/

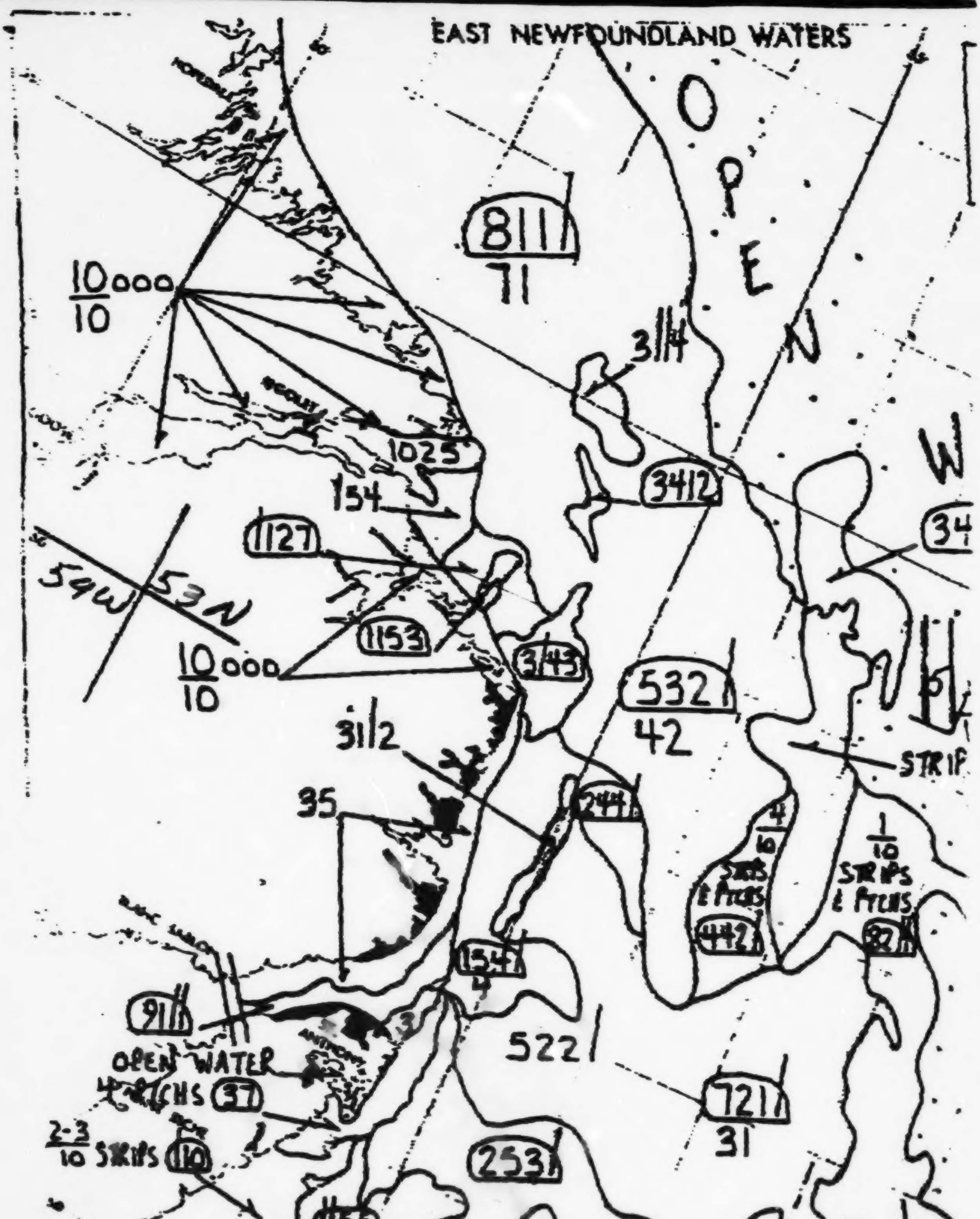
G

APPENDIX G

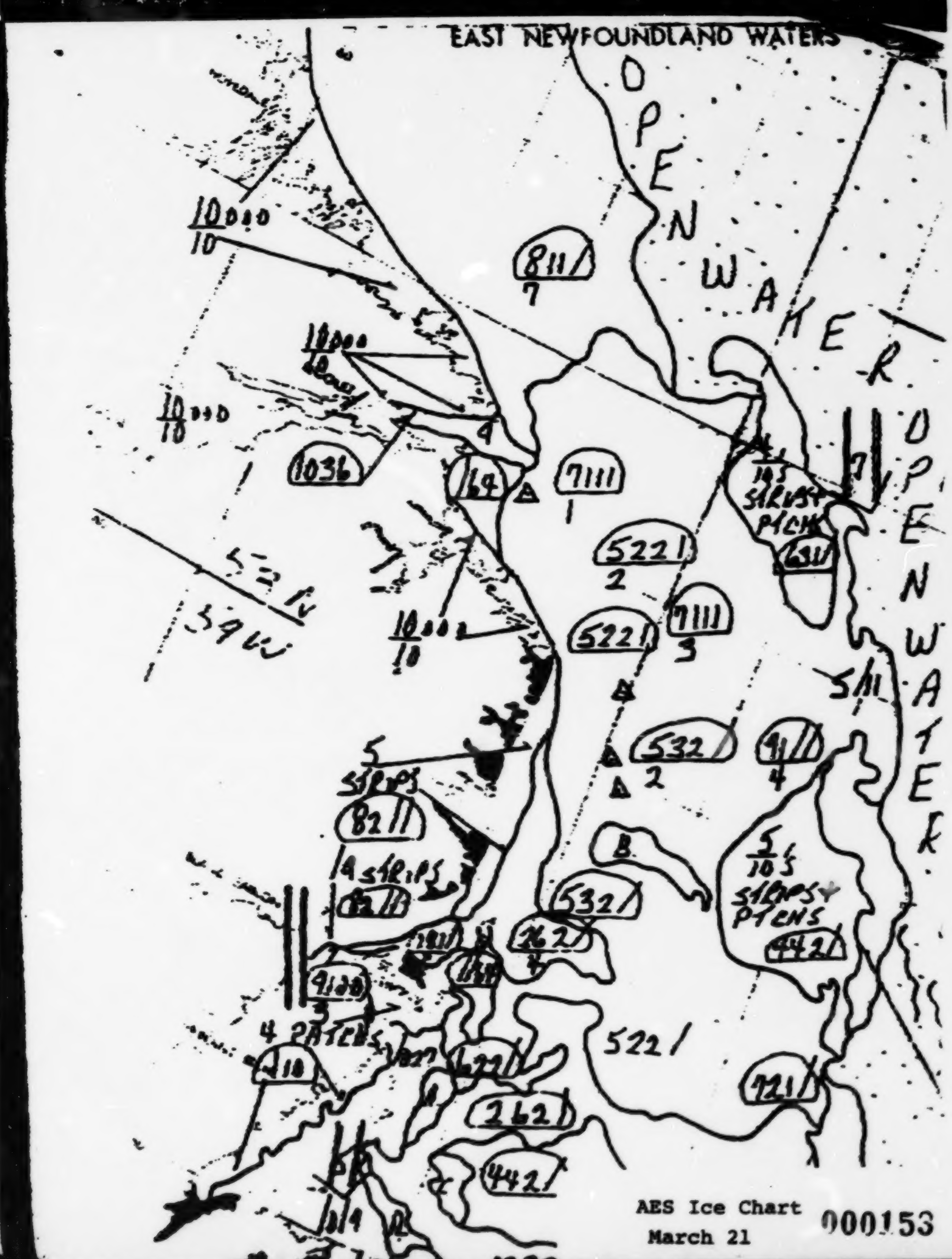
Atmospheric Environment Service

Current Ice Charts

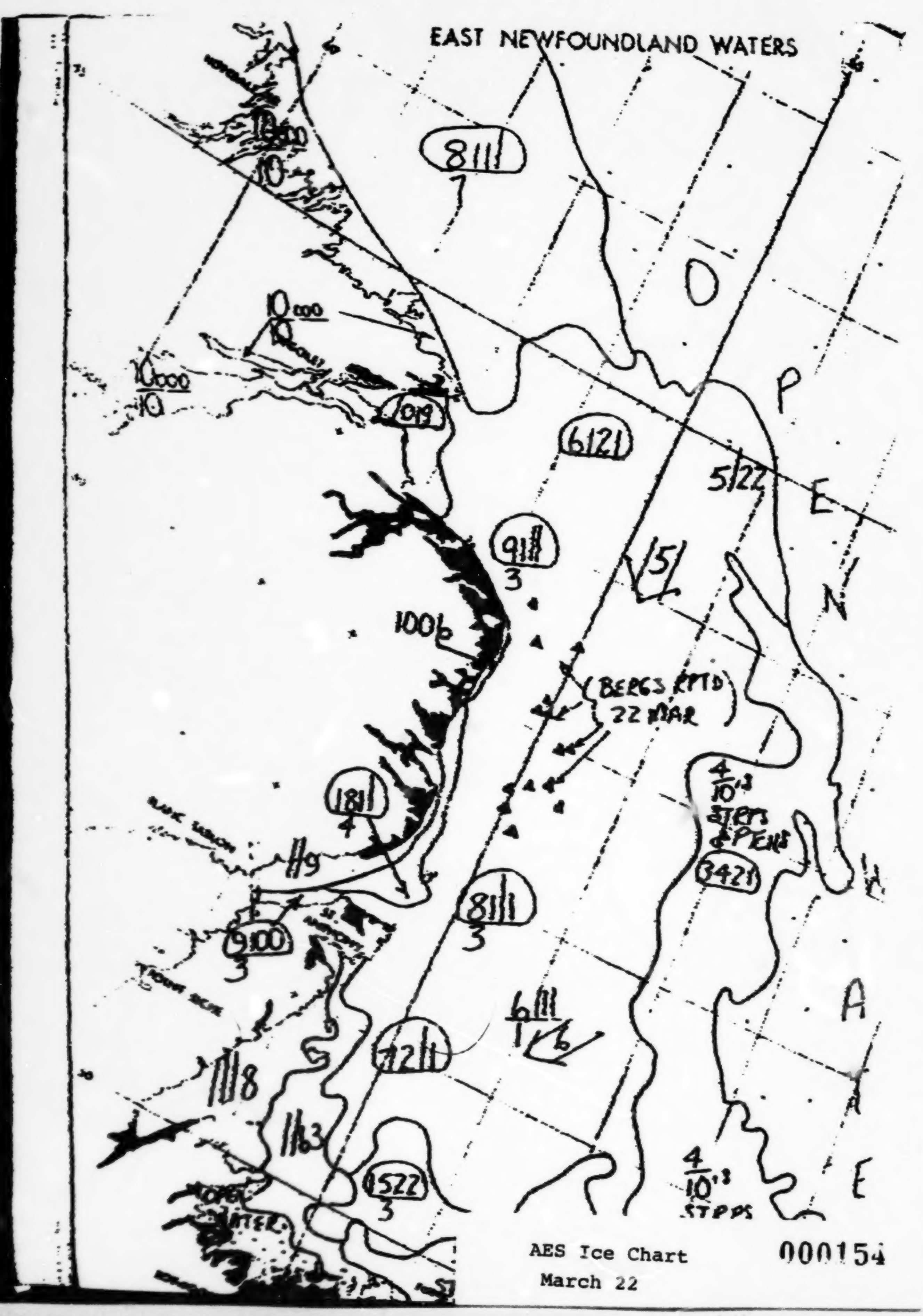
Note: The key for interpreting these charts is included at the end of this appendix.


EAST NEWFOUNDLAND WATERS
OPEN W
8111
71
10/10 000
1025
154
1127
54W
53N
1153
10/10 000
343
3|4
3412
34
532
42
31|2
STRIP
35
244
4/10 STRIPS & PTCHS
442
1/10 STRIPS & PTCHS
82
154
4
911
OPEN WATER
4/10 PTCHS 37
2-3/10 STRIPS 110
522
721
31
253
1155
PTCHS
3115
235
1122
1/10
3034
OPEN WATER
1243

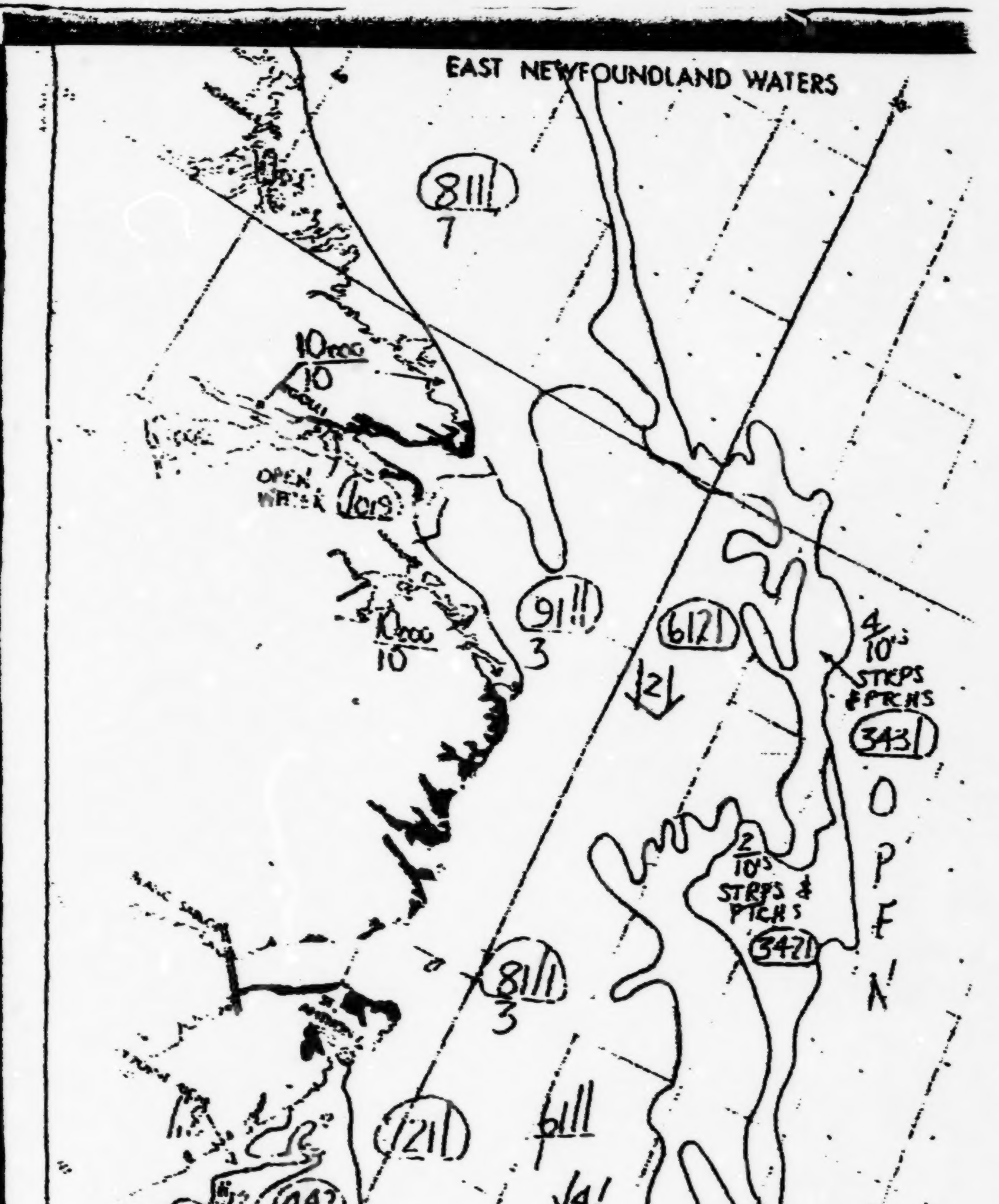
AES Ice Chart
March 20


EAST NEWFOUNDLAND WATERS
OPEN WATER
OPEN WATER
10
10
10
10
10
10
10
10
1036
64
7111
1
811
7
4
5221
2
5221
7111
3
532
2
9
4
5
STRIPS
8211
9 STRIPS
8211
5
10 S
STRIPS + PTCHS
442
10 S
STRIPS PTCHS
631
5/1
7
B
532
262
9120
3
4 PATCHES
210
522
721
262
442
39W

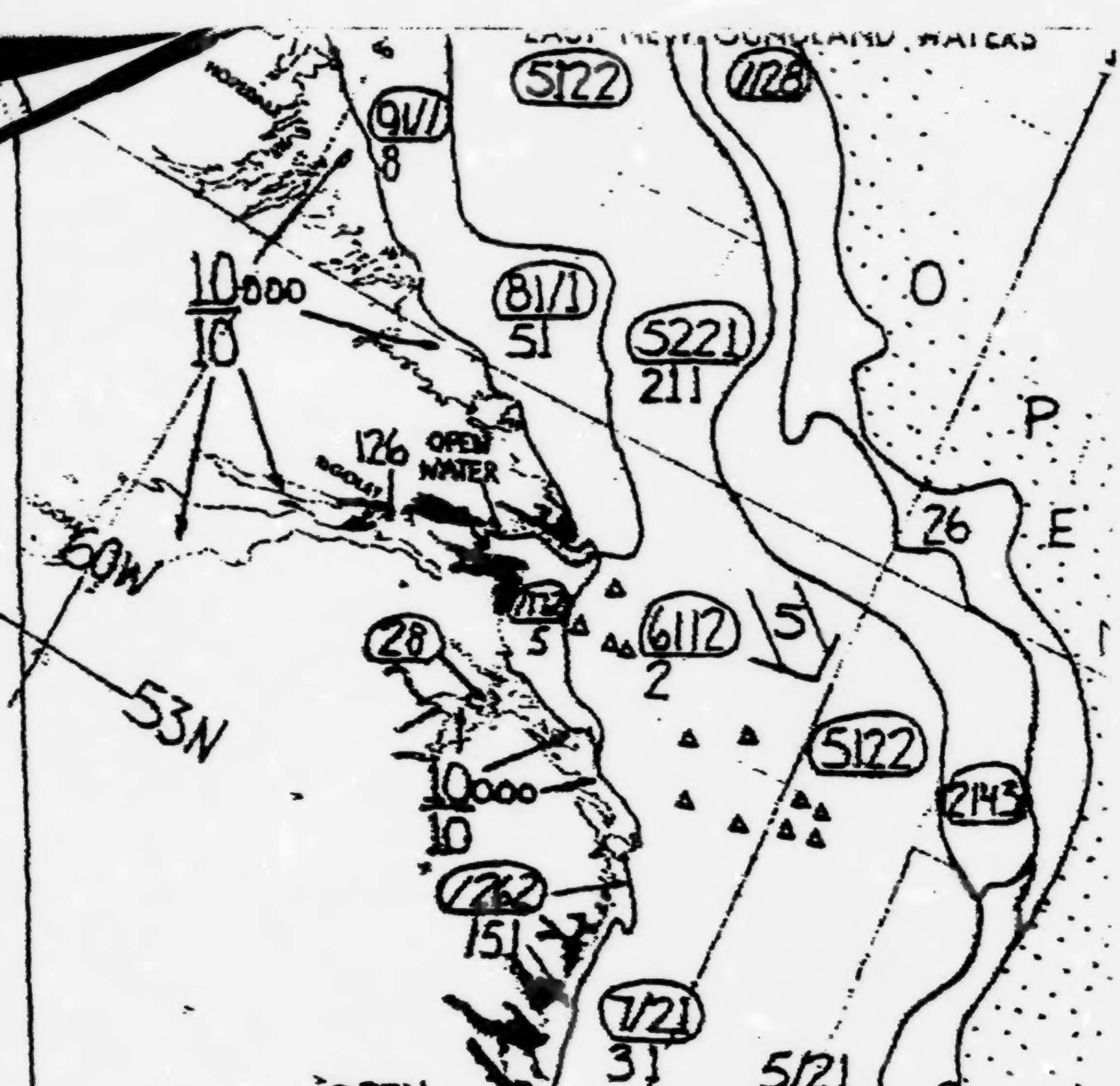
AES Ice Chart
March 21


EAST NEWFOUNDLAND WATERS
8111
7
10000
10
10000
10
10000
10
019
6121
5122
9111
3
151
100b
(BERGS RPTD
22 MAR)
181
4
9
9100
3
8111
3
4
10'3
STRPS
& PTCHS
3421
6111
1
6
7211
8
63
1522
3
4
10'3
STRPS
O
P
E
N
A
E

AES Ice Chart
March 22

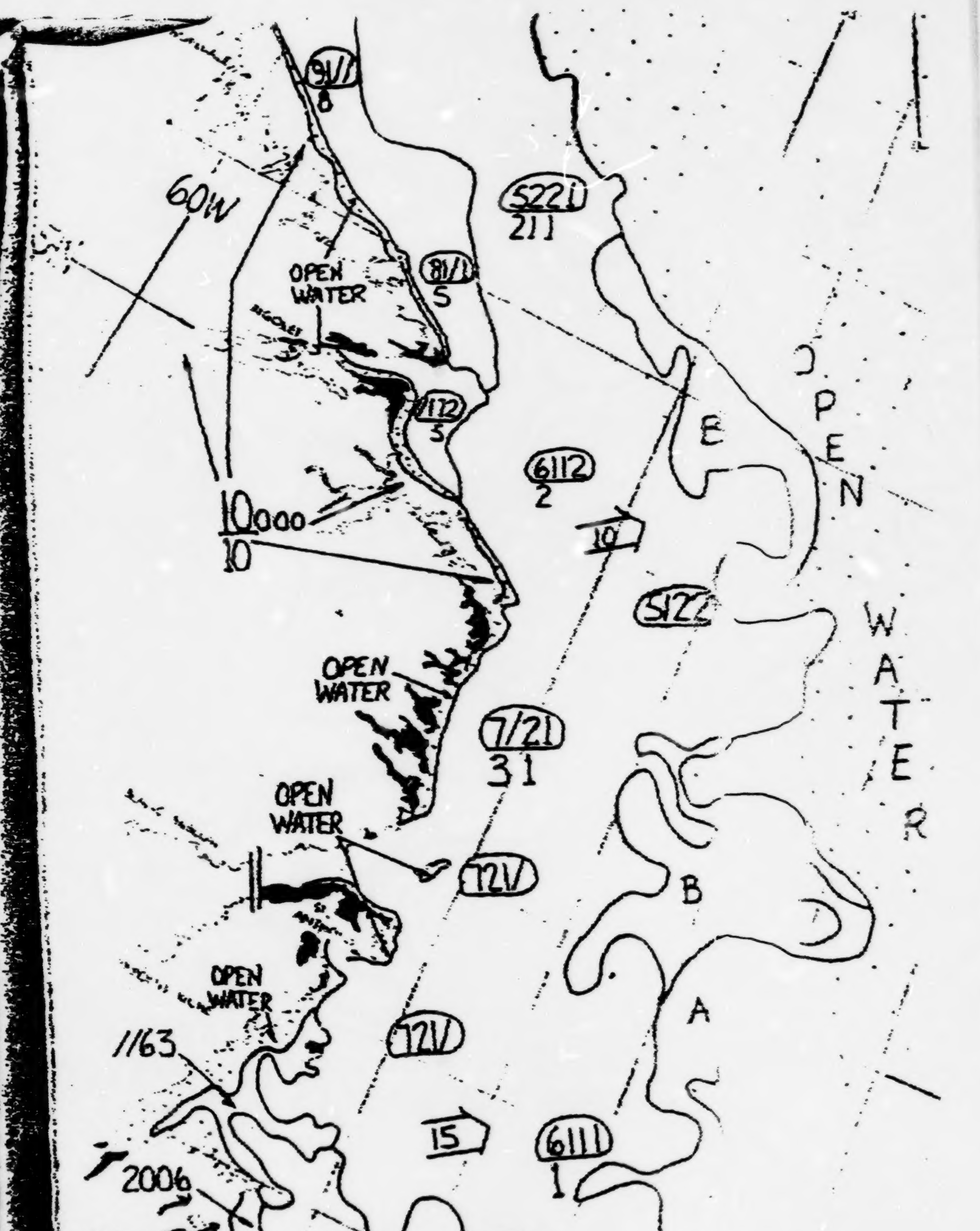

EAST NEWFOUNDLAND WATERS
8111
7
10ooo
10
OPEN WATER
1019
9111
3
6121
2
4/10's
STRPS &PTCHS
3431
10ooo
10
OPEN
2/10's
STRPS & PTCHS
3421
8111
3
7211
6111
4
442
1572
2
262

AES Ice Chart
March 23

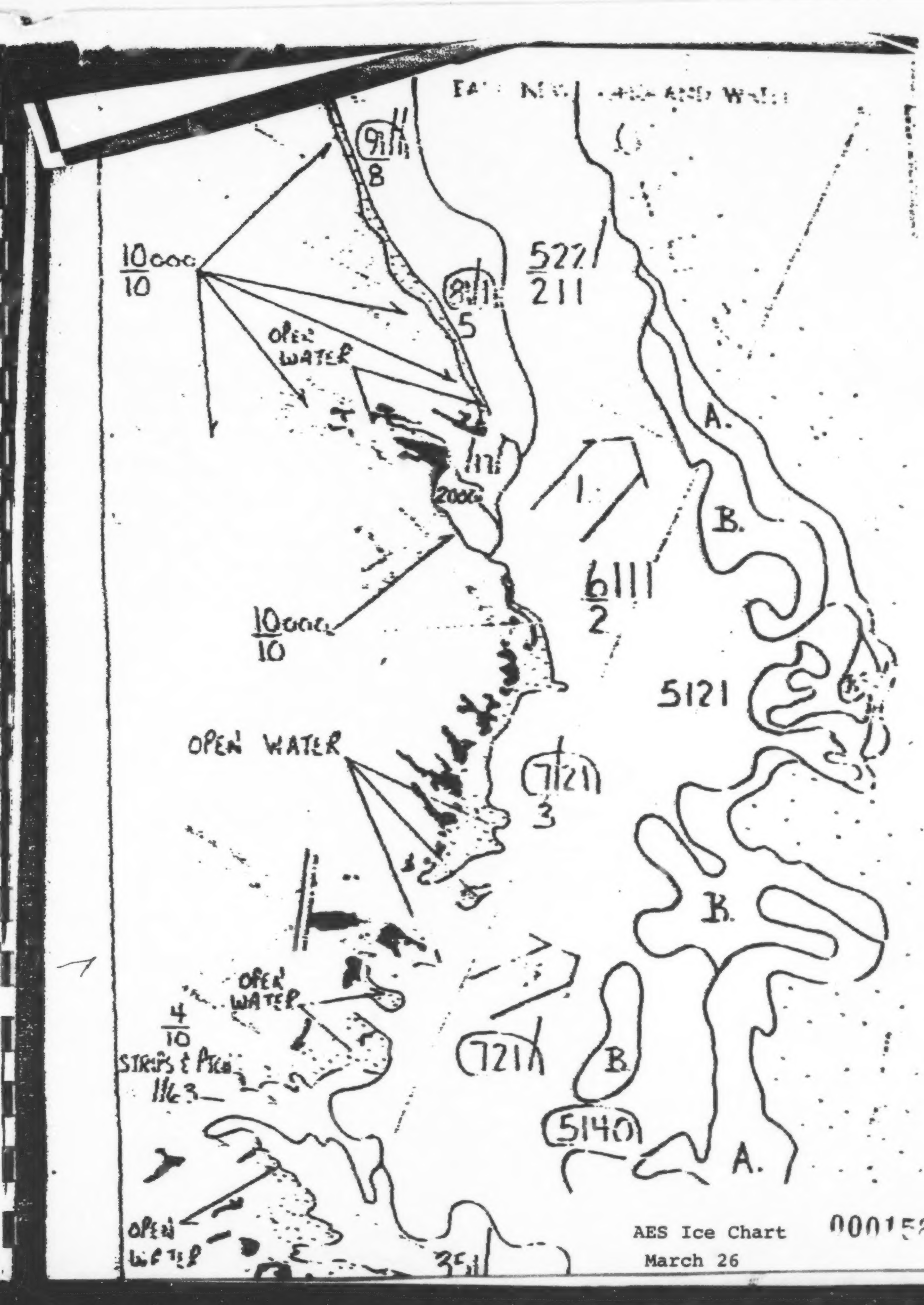

EAST NEWFOUNDLAND WATERS
5122
1128
91/1
8
10/10 000
81/1
51
5221
211
O
P
E
N
126
OPEN WATER
26
60W
53N
6112
2
5
28
5
5122
10/10 000
2143
1262
151
7/21
31
5/21
OPEN WATER
611
1/6
B
A
OPEN WATER
7121
8
1/163
442
6111
1
OPEN WATER
420H
4671

AES Ice Chart 000156

March 24


9///
8
60W
5221
211
OPEN WATER
81/1
5
7/12
3
OPEN
6112
2
E
P
E
N
10000
10
10
5122
W
A
T
E
R
OPEN WATER
7/21
31
OPEN WATER
72//
B
OPEN WATER
72//
A
1/63
15
6111
1
2006
OPEN WATER

AES Ice Chart
March 25


FAST NEW ... AND WHITE
10 0000 / 10
OPEN WATER
9/// 8
8/1 5
522/ 211
A.
1.
B.
2000
6111 / 2
10 000 / 10
5121
OPEN WATER
7121 3
K.
OPEN WATER
4 / 10
STRIPS & PATCHES
1163
721
B.
5140
A.
OPEN WATER

AES Ice Chart
March 26

KEY TO ICE SYMBOLS

CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or greater}}$$

$$\frac{\text{Cmy Csy Cfy Cgy Cgw Cg Cn}}{\text{Nmy Nsy Nfy Ngw Ng Nn}}$$

Example $\frac{20.3410}{1\quad 23}$

2-2/10's Multi Year of which
1 1/10 is Medium Floe or Greater
0- No Second Year
. - Decimal Point
3 - 3/10's First Year of which
2 2/10's is Medium Floe or greater
4 - 4/10's Grey White of which
3 3/10's is Medium Floe or greater
1 - 1/10 Grey , no Mediam Floe or greater
0 - No New

SNOW COVER

Sn/(n)

(n) tenths on ice

TOPOGRAPHY

$\frac{\wedge\ \wedge}{(n)}$ Rafted ice

$\frac{\wedge\wedge\wedge}{(n)}$

SURFACE FEATURES

Sn/Re Rd Hy Pd Th+ F

$\frac{\Omega\ \Omega}{(n)}$ Hummocks

(n) number of tenths

STAGE OF MELTING

$$\frac{Pd}{(n)\ (n)\ Th+\ (n)\ F}$$

(n)= tenths on ice
(n) th = tenths thaw holes
(n)F = tenths frozen

e.g. 6/120
6- 6/10 Snow Cover
/ -Slant
1 - 1/10 Rafting
2 - 2/10 Ridging
0 - No Hummocks
1 - 1/10 Puddling

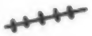
THICKNESS OF ICE AND SNOW

T/n · S/n (n) - nearest inch

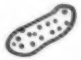
ICE OF LAND ORIGIN

△ - (n) Icebergs
⌂ - (n) Bergy Bits and growlers
Optional : (n) number in area

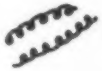
WATER FEATURES


Creek

= Lead

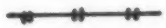

Polynye

UNDER CAST


Limits

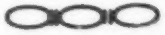
BOUNDARY

——— Observed visually


Observed by radar

- - - - - - Assumed

○ ○ ○ Limit of Observed date


Limit of radar date

POOR

QUALITY

ORIGINAL